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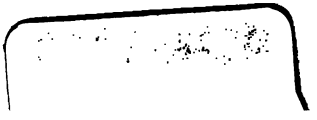

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LONDON:
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WHAT IS MATTER?

WHAT IS MATTER?

BY AN

INNER TEMPLAR,

AUTHOR OF "MORE LIGHT: A DREAM IN SCIENCE."

"And things are not what they seem."

LONGFELLOW.

LONDON:

WYMAN & SONS, 74-75, GREAT QUEEN STREET,

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PREFACE.

SO many attempts have been made, in all ages, by philosophers, to solve the problem of the world's existence, and so signally have all these attempts failed, that men have come to believe that it is one of the mysteries which must for ever remain a mystery. It may be doubted whether there is in this highly enlightened age a man of any *status* in the scientific world who would go so far as Professor Playfair in expressing a hope that Bacon may be right in ascribing to philosophy that perfection which so many believe it is never destined to reach; certain it is that the

writer has never found one who did other than denounce any attempt to solve the problem of knowing the world *per se*, and who would not, probably, consider him that made the attempt as impertinent in the highest degree, and destitute of all regard for the fame of those mighty intellects which have declared its solution impossible.

"What is Matter?" has been so long a metaphysical scarecrow—so long "the horrible example" set by physicists before their followers—so long a prop on which to hang all the tattered trophies of dead and dying systems of philosophy—that the writer has doubts as to his being able to remove the veil from men's eyes. He asks but a fair field and no favour; if he receive this, he feels confident that the delusion will be for ever swept away.

CONTENTS.

PART I.

CHAPTER I.—The Question "What is Matter?"—Speculation — Hypotheses — The Baconian Method ... ...*page* 1—5

CHAPTER II.—The Birth of Physical Science—Thales—Anaximenes—Diogenes—Heraclitus—Anaxagoras—Zenophanes—Pythagoras—Egyptian Priests—"Uncivilized Origin of Man"—Ideas: Ancient and Modern—Ideas: how produced?—Simultaneous Discoveries—Early Speculation in the Light of Modern Research—One Original Matter?—Ancients and Moderns compared ... ... 6—13

CHAPTER III.—First Attempt at an Atomic Theory—The Two Views of Atoms—Empedocles—Leucippus: the Founder of the Atomic Theory—Democritus—Mr. Lewes's Opinion

of the Atomism of Democritus—The Value to be attached to this First Effort to comprehend the Universe—Dr. Daubeny's Opinion of the Most Primitive Philosophy *p.* 14—16

CHAPTER IV.—The Sophists — Socrates — Plato — Aristotle—The Sceptics — Epicurus — Zeno: Founder of the Stoics—The Academicians 17—19

CHAPTER V.—Science, Philosophy, and Faith—The Alexandrian Schools—Plotinus—The Three Questions propounded by Ancient Metaphysics—How the Alexandrians answered them... ... ... 20—22

CHAPTER VI. — Bacon: the Inductive Method — Descartes: the Deductive Method — Descartes's "Theory of Vortices"—Spinoza —Hobbes—Locke—Leibnitz—Boscovich—Dr. Good's Criticism on Boscovich's Doctrine —Entities and Nonentities—The Idea of Extension — Dr. Daubeny's Criticism on Boscovich's Doctrine—How the best Physical Schools answer the Question "What is Matter?"—Dr. Priestley—Is Substance anything more than Powers of Attraction and Repulsion?—Dr. Good's Remarks on this Question: their Value—Newton: his View of Atoms ... ... 23—34

CHAPTER VII.—Faraday: his Views on Matter—Dr. Daubeny's Estimate of Faraday's Views

—Centres of Force—Matter and Powers of Matter—Two Theories of Atoms—Mutual Penetrability of Atoms—Ether and Ordinary Matter: What are their Powers?—Lines of Force—Radiation ... ...*page* 35—51

CHAPTER VIII.—One Nature of Force?—Action of Force upon Force—Common Sense as a Guide — Impenetrability — Porosity — Can Force be Annihilated?—The Ether assumed in the Undulatory Theory of Light—Original Matter: its Uses—Sir Henry Holland on the Physical Condition of Space—Is Space Void?—Objections to a Medium of the most Extreme Tenuity—Argument against the Idea of a Vacuum—Plena and Vacua—Electricity—Light—Sir Henry Holland on the Constitution of Atoms—"The Old Problem of Materialism" ... ... 52—63

CHAPTER IX.—Berkeley—Is the Substratum Unknowable?—Spirit—Do Objects exist *per se*? —Why Berkeley failed—Hume ... ... 64—68

CHAPTER X.—Kant—Lewes—Noumena and Phenomena—The Dualist System—Opinions of the More Modern German Schools of Natural Philosophy — Fichte — Schelling — Hegel — Eclecticism—Comte—Positive Science ... 69—76

CHAPTER XI.—A New Method—Scientific Eclecticism—The Result ... ... 77—80

PART II.

CHAPTER I.—Phenomena but Manifestations of Force—Effect of such Knowledge ...*page* 81—83

CHAPTER II.—The Rise and Development of the Universe — Logical Inference — Huygens — Playfair—The Universe in its First Stage of Existence — Nebulous Clouds — Our Solar System: its Formation—The Moon—The Simultaneous Appearance of the Sun, Moon, and Earth—The Milky Way—Herschel's "Gauge" of the Heavens — Lambert — Wright: his Explanation of the Milky Way —The Galactic Poles—Thickness of Stratum of Milky Way ... ... 84—91

CHAPTER III.—Newton's Hypothesis on the Revolution of the Planets—The Universe a Great Sphere—The Origin and Solar Revolution of the Planets ... ... 92—95

CHAPTER IV.—Action of Light upon Atoms—The Two Great Theories of Light ... ... 96—97

CHAPTER V.—The Chief Hypotheses of the Corpuscular or Emission Theory—Do the Rays of Light describe a Trajectory?—The Great Stumbling-block in the Corpuscular Theory —The Essential Conditions on which the Newtonian Doctrine is founded ... ... 98—104

CHAPTER VI.—The Chief Hypotheses of the Undulatory Theory—A Most Formidable Objection to this Theory—Shadows ...*page* 105—110

CHAPTER VII. — Requirements from a True Theory ... ... 111—119

PART III.

CHAPTER I.—Spheres of Force—How the Different Modifications of Matter are Produced—An Atom of Original Matter—An Atom of Hydrogen—An Atom of Oxygen—An Atom of Water—An Atom of Glass—An Atom of Diamond — Brewster's Conjecture on the Nature of the Ether ... ... 120—127

CHAPTER II.—Surface-Atoms—A Surface-Atom of Glass — Why Surface-Atoms are Different from Those in the Interior — Action of Surface-Atoms on the Rays of Light — Isolated Atoms ... ... 128—131

CHAPTER III.—Geometrical Construction of a Surface-Atom of Water—Geometrical Construction of a Surface-Atom of Glass—Geometrical Construction of a Surface-Atom of Diamond—Refractive Indices of Water, Glass, and Diamond ... ... 132—135

CHAPTER IV.—Velocity of Light—Rays of Light: What they are, and their Effects upon the Surface of the Globe—Changes which Rays of Light undergo ... ...*page* 136—139

CHAPTER V.—Refraction and Reflexion—Newton's Fits of Reflexion and Transmission—New and Curious Property in regard to the Motion of Rays of Light—On the Alternate Reflexion and Refraction of Rays ... ... 140—146

CHAPTER VI.—Refraction—Snellius—"The Law of the Sines" stated and discussed—A Theoretical Investigation of this Law—Refraction of Rays through Water, Glass, and Diamond at Different Angles of Incidence—The Value of μ—Huygens' Supposition on the Velocity of Light shown to be True—Young and Fresnel on the Velocity of Light in Media—Connexion between the Angle of Incidence and the Velocity—In Refraction, Rays incident at 90° and 0° ... ... 147—154

CHAPTER VII.—Refraction through a Plate of Glass with Parallel Sides—Angle of Incidence necessary to produce an Angle of Refraction equal to the Critical Angle of the Substance ... ... 155—159

CHAPTER VIII.—The Critical Angle—Total Reflexion ... ... 160—163

CHAPTER IX.—Reflexion—The Law by which it takes place—Velocity of Reflected Ray equal to Velocity of Incident Ray—Ray Incident at Polarizing Angle—Ray Incident at Critical Angle—Ray Incident at Angle less than Critical Angle—Absorbed Rays—Observation of Laplace on Double Refraction *page* 164—168

CHAPTER X.—Media: Dense and Rare—Critical Angle of Water, Glass, Diamond, and Chromate of Lead—Has Air a Critical Angle?—Explanation of the Great Reflexion from all Smooth Surfaces at a very Great Angle of Incidence—Are Exterior and Interior Reflexion produced by the Action of the same Law?—Relation between Reflected and Refracted Rays—How do the Surface-Atoms of Two Contiguous Media affect Rays of Light?... ... ... 169—174

CHAPTER XI.—Refraction of Rays from one Medium into another—The Law Regulating the Passage of such Rays—The Passage of a Ray from a Vacuum through Contiguous Plates of Water and Diamond into a Vacuum ... ... 175—177

CHAPTER XII.—Dimensions of Atoms—Thicknesses of Air, Water, and Glass at which Light ceases to be Reflected—Length of Axis of Atoms of Original Element, Air, Water, Glass—Equatorial Diameter of Atoms ... 178—181

CHAPTER XIII.—Angle of Polarization—Polarizing Angle for Diamond, Glass, and Water—Completely Polarized Ray—Brewster's Law—Angle of Maximum Polarization of Atmosphere—Professor Tyndall on the Polarization of the Sky—Polarizing Angle of the Light of the Sky—Of what Substance is 45° the Polarizing Angle?—Colour of the Sky *p.* 182—190

CHAPTER XIV.—Conclusion ... ... 191—195

WHAT IS MATTER?

PART I.

CHAPTER I.

"It is by no means necessary that hypotheses should be true, nor even seem true; it is enough if they reconcile calculation with observation."—*Copernicus.*

TO one of an inquiring turn of mind, the mysterious question, "What is Matter?" cannot but have presented itself early in his career, especially where that career is literary or scientific. He may, indeed, have been so bold as to have put the question to some friend well advanced in years and modern science, and had his inquisitive ardour repulsed by a smile of pity. Most likely the only answer would be a warning not to meddle with such

abstruse subjects. If our inquirer should dare to suggest the advisability of taking this or that into consideration on the point, the piteous smile becomes a sarcastic one, and the experienced philosopher pooh-poohs his suggestion, and either in candour or anger tells him that it is not at all likely, if the greatest philosophers, from Thales downwards, could not clear up the mystery, that *he* would add anything to effect its solution. Pitied and snubbed, our inquirer may take the advice and close his mind for ever to this and all other subjects bordering on the speculative, and spend his days a commonplace man, useful in his day and generation—a poor curate, a country surgeon, or a kind of superior village schoolmaster. But he may be above being pitied; he may endure the snubbing, and refuse to follow the advice; he may believe, with Shakespeare, that

> "There are more things in heaven and earth
> Than are dreamed of in our philosophy,"

and feel that though the heights of fame tower high, and the path up is rugged and steep, men have reached and will reach them; and he

may, by patient struggling, be enabled to cut his name on her highest rocky peak.

It may be argued that for one to begin where philosophers generally end is presumptuous; but it has at least this merit, it is beginning at the beginning. It may be argued that it leads to speculation,—that the present is an age of speculation,—that within the last two hundred years some of the wildest notions that it were possible to be evolved from the brain of man have been launched upon the world, impudence upholding some, sophistry others. But because nine have no more solid foundation, it does not follow that the tenth may not be on a good basis; and even in regard to a method, the wrong ways may be many, the right but one. And yet who would say, let us have speculation—guessing in the dark? Although if we could but see the original design—the rough outline, as it were—of some of our greatest discoveries, they would be found in appearance like the original manuscript of some of our poets' verses, and beginning with a wild hypothesis.

"Non fingo hypotheses," said Newton; but

we judge from his own practice that he did not condemn hypotheses derived from some sort of observation or experiment. What he doubtless objected to was the production of a brain in which the ideas for the most part chased one another up and down, and scrambled, and tumbled, and jostled each other in confusion. An hypothesis, then, which has been gradually evolved from facts, cannot but have a certain amount of merit about it. An hypothesis *à priori* is next to impossible to a finite mind otherwise than as a guess, and then it has but an ephemeral existence, if it be not supported by observation and experiment. If we look into the various theories respecting matter held by the ancients, we cannot fail to notice how strikingly this is borne out—pure guesses at truth it may be, and some very wide of the mark. Here and there we get a marvellously near approach to the truth—it may have been a guess, it may have been an intuition; certainly it was not an inference from sensation—experiment they had none.

And even down to the time of Bacon there was little better; each generation either think-

ing in the old grooves, or not thinking at all, content to take for granted that which its predecessor had bequeathed it, on no other authority than a name. But a new era opened; a new school was founded—a school which worked with experiment and brain combined, which made experiments and drew inferences, and experimented again to prove the inferences or reject them. This was the only sure method upon which to work: that it has been eminently successful the history of knowledge in all its branches testifies. But even with the universal acknowledgment of this method over every other, there are not wanting instances in modern science which are contrary to the spirit of it.

CHAPTER II.

LET us, however, trace the development of thought on the important subject of Physical Science from the earliest times, and ascertain our real knowledge of it as the result of the latest investigations. There can be no surer method of learning our whereabouts—no better plan for discovering whether we have any theory comprehensive enough to grasp the problem of the Universe, and if not, what reliable materials we have on hand suitable for framing one; involved in which will be the answer to the question which stands at the head of this work.

Among the Greeks, the earliest philosopher of distinction, Thales, the founder of the Ionic school, believed that everything was produced

from and reduced to *Water*, which he considered the original element.*

Anaximenes, the third in this school, held that Air—he called it Life—was the single original element out of which all material things were formed.

Diogenes, the pupil of Anaximenes, maintained that Air was not Life, but that through which Life manifested itself; Life is a Force or Intelligence; hence Force or Intelligence was the *prima materia* of all things, and the Universe a living being.

Heraclitus, who held that all knowledge was derived through the senses, maintained that Fire was that from which everything was produced. This Fire was not flame, but an ether, which he declared was God.

Anaxagoras, the most illustrious of the Ionic school, rising above the mere material, held that there was a Supreme Intelligence, who

* The writer begs to acknowledge his indebtedness to Mr. Lewes's "History of Philosophy," and to Dr. Daubeny's "Atomic Theory," for most of the facts concerning the doctrines of philosophers in the following pages.

gave form and order to the matter of the Universe. In regard to the material, he believed that it was formed from elementary seeds of endless variety, which existed from the beginning; that for as many different substances as existed in nature, there existed as many distinct original portions of first matter.

Zenophanes, the founder of the Eleatic school, maintained that the whole of nature was God; from which we may infer that with him Matter was not an inert something, nor yet a something with a moving or animating principle, but the animating principle itself; in fact his philosophy was Pantheism. Thales himself held that some forms of matter, as the loadstone, possessed a soul.

Pythagoras, the founder of the third school of philosophy, held that number was the basis or essence of all things; he conceived matter to consist of monads, which he may have derived from the Egyptians.

Indeed it is very probable that the Egyptian priests had such a knowledge of science as would not be credited in this day. Those who hold the doctrine of the "uncivilized origin of

man" will of course question this; but if it be considered that some of the most important modern ideas in metaphysics are essentially the same as those propounded thousands of years ago, there will be good ground for questioning the development of civilization. Man's fancy is very nearly the same in all ages: we see it in poetry, which belongs to no age or nation; and the chemical process—if such it be—which produces ideas, must be essentially the same whilst the materials are the same. A philosopher then, unprejudiced and unbiassed, looking away into boundless space and eternity, will have ideas essentially the same, whether he be an ancient or a modern. In this way we may account for the rise of ancient ideas in modern minds. This knowledge then, being exclusively in the hands of the Egyptian priests, gradually degenerated and finally died out; the same knowledge springs again spontaneously in some other race, grows with its growth, and perishes with it; again, as if by some mysterious law, it appears with some other nation. It is perhaps the lingering trace of a spontaneous power once possessed by the

mind of man—a power of intuition which has almost faded away. In this manner may be explained the knowledge of the same arts and sciences in nations so remote from each other that they could not have borrowed. What volumes have been written to prove that such a nation must have borrowed this from one, that from another! Whence did these get it? Was it intuitive? Was it invented? Why not with that nation? You will perhaps answer that it is not likely that both would think of the same thing. But examine their brains, and they will be found identical. They were affected in the same manner through the organs of sensation; were not the same sensations produced? And where the material of the brain—essentially the same in both—wrought in secret, the resulting ideas must in many cases have been the same. Suppose we were told—as indeed we have been—that the Chinese had a knowledge of gunpowder, or how to apply the peculiar property of the magnet, quite independent of European influence, would it do to say that it was not likely that they would both think of

the same things? In the same way may be traced the origin of many customs found in nations not only far removed from each other, but in some cases nations, one of which flourished thousands of years after the other, as the North American Indians and the ancient Egyptians or the Jews, who have many very remarkable customs in common. How, also, can we explain the fact so very often observed, of two persons in different parts of the world making the same discovery simultaneously? But perhaps of all the arguments the best is one already mentioned in other words, that the choicest ideas of the choicest modern brains only prove the superior powers of mind which animated this world's earliest philosophers.

Take the subject in its subtlety, or take it in its simplicity, and, comparing it with modern research in physics and metaphysics, we cannot but admire the depth of wisdom. That which Berkeley maintained—that which many distinguished Germans held—the non-existence of a material world, in fact, that that which we call matter is not matter at all, the

Hindoos at a very early period believed; and that doctrine which declares the whole universe to be God, was it not maintained by the founder of the Eleatic school? The reader must not suppose that he is asked to admire Pantheism, but that spirit which can look beneath the mere outward show, which recognizes that "things are not what they seem"—a spirit which manifests a superior order of mind, though carried to an extreme, it ends in Idealism or Pantheism. All modern physical research tends to show that that which mankind looks upon as inert matter is by no means what it appears.

So much for the subtlety of the subject; let us now look at it in its simplicity. What has modern research done for us here? It has tended to show that the laws of Nature, and possibly the elements, are very simple. In regard to the belief held by some, that there is but one kind of matter—one original element out of which all material things have been created—it must be confessed that modern philosophers as a body seem opposed; if one will, however, but carefully watch the progress of science itself, there can be little doubt of its

truth. But in this, as in the immateriality of existing things, we seem to have been anticipated by the ancients. They had not the power of proving either, neither have we; they believed both, we have yet to be convinced; they were credulous, we are sceptical; they took things for granted, we must see before we are satisfied.

CHAPTER III.

LEAVING then Pythagoras and his monads, which—with the exception of Anaxagoras, who believed in elementary seeds of endless variety—is the first instance of an attempt to put forward anything like an atomicity of matter, let us endeavour to ascertain what progress was made by the ancients in the theory of atoms.

It may, however, be well to mention here that there existed in ancient as well as in modern times two views on this point:

1. That matter consists of individual atoms.
2. That it is infinitely divisible.

Empedocles held the latter opinion, and that there were four elements: fire, air, water, earth—all modifications of the Original Matter. These four by the action of two forces—Love

and Hate—combined and produced all the various forms of matter.

Leucippus, who was really the founder of the Atomic Theory—though this title is generally conferred on Democritus, who greatly developed it—it is almost superfluous to say believed in the existence of atoms. He also held that the sun, moon, and earth were formed by the gradual contraction in dimensions of aggregations of matter in hollow spheres.

Democritus conceived an atom to be invisible, intangible, indivisible, and self-existent. All things were only modes of configuration, combination, or position of atoms, and were alike in essence, different in phenomena alone. Quality was not inherent in the atom, but was a mere phenomenon resulting from combination with other atoms. "The Atomism of Democritus," says Mr. Lewes, "is one of the profoundest speculations yet reached by human subtlety;" and yet with Democritus there was no attempt to prove the point. Does Mr. Lewes deny that it is capable of proof, and that the profundity consists in Democritus having intuitively arrived at that which at the present

day is believed to be the true solution of the question?

Here, then, we have in a small compass the earliest effort of philosophy in the ancient world. Search the history of all subsequent speculation, and it will be found that this first effort to grasp the great problem of the universe has never been surpassed. It was the more successful, so far as it went, in that it was the fruit of minds not yet entangled in the meshes of a later philosophy. Those were days when men had not yet learned to waste their time in metaphysical disquisitions and logical hair-splitting; days when the arts of metaphysics were valueless, because unknown; and it is only now when we have learned their worthlessness, and are getting back to that early simplicity of thought, that we appear to be approaching the truth. "It is remarkable," says the late Dr. Daubeny, "that the most primitive philosophy of any with which we are acquainted—that philosophy from which Plato adopted his *Ideas*, Aristotle his *First Matter*, affords a nearer approximation to the principles of modern science than the doctrines of the Greek schools that succeeded it."

CHAPTER IV.

WHO were these philosophers that followed?

First came the Sophists, proclaiming the vanity of everything that had preceded them, and that hope lay alone in politics and rhetoric.

Socrates, trusting to morals, and looking within himself for truth.

Plato, the Realist, holding aloft abstract ideas as the only real existences, at the same time believing in an original matter without properties, and infinitely divisible.

Aristotle, with his threefold division of matter into substance, higher substance, and absolute substance, or God himself, and atoms actually, though not potentially, divisible.

Then came the Sceptics, looking to common sense, and declaring that the mystery of exist-

ence is unfathomable, as there is no criterium of truth, since we know *phenomena* alone, and cannot know *noumena.*

What with politics and rhetoric, morals and abstract ideas, absolute science and common sense, darkness seems to cover the earth, a dense fog to encompass us; we have quitted sight of land, our barque is on the wide, wild ocean. No wonder that men became Sceptics!

At this point in our history science is not unlike the man who fell among thieves; we have perhaps a priest and a Levite in those ancient philosophers who follow, but at most they cast a sympathizing glance, and then pass on the other side.

Epicurus, the first to follow, though his great aim was to discover true happiness, devoted some attention to physics. He held that before the formation of the universe, space and matter existed in their elementary form—*space* as absolute void; *matter* as atoms inconceivably minute, infinitely hard, and of various shapes.

Then came Zeno, founder of the Stoics, who held that there were two elements: the *passive*, primordial matter, consisting of mere points

without extension; the *active*, reason or God, who endowed the passive element with laws.

Following him came the Academicians, declaring the impossibility of revealing the real nature of things, the deceptiveness of all human knowledge, and themselves Sceptics.

CHAPTER V.

AGAIN Science starts, now to soar away with Philosophy, who has made friends with Faith.

The Alexandrian schools arise with Plotinus as their leader, asserting that the Principium is an Indeterminate Ineffable, a something beyond existence, which logically is reduced to nothing.

"In reviewing," says Mr. Lewes, "the history of Greek speculation, from the 'Water' of Thales to the 'Absolute Negation' of Plotinus, what a reflection is forced upon us as to the vanity of metaphysics! Was, then, all this labour vain?" No; it was "the education of the human race." It taught that "the Infinite cannot be known by the finite, and man, as finite, can only know phenomena."

"Metaphysics propounds three questions:—

"1. Has human knowledge any absolute certainty?

"2. What is the nature of God?

"3. What is the origin of the World?

"The Alexandrian school answers thus:—

"1. Human knowledge is necessarily uncertain. This difficulty is got over by the hypothesis of an ecstasy, in which the soul becomes identified with the Infinite.

"2. The nature of God is a triple unity.

"3. The origin of the world is the law of emanation.

"God as unity *is* not existence, but he becomes existence by the emanation from his unity (intelligence), and by the second emanation from his intelligence (soul), and this soul in its manifestations is the world.

"Either God made the world or he did not. If he made it, whence did he make it? Logic said he could not make it of nothing, for nothing can come of nothing. . . . The Christian . . . . said God created the world out of nothing, by the mere exercise of his omnipotent will.

"The Alexandrians said the world was dis-

tinct from God *in act* rather than *in essence;* it was the manifestation of his will, or of his intelligence. Thus the world is God, but God is not the world. Without the necessity of principles, the distinction is preserved between the Creator and the created. . . . God is in his very essence a Creator. . . . God is the only existence. He is the real existence, of which we and other things are but the transitory phenomena."

From this time down to the days of Bacon little was done beyond what has been happily termed "grinding the air in metaphysical mills."

CHAPTER VI.

BACON opens up a new era by laying the foundation of the Inductive method. He does not attempt to answer the abstruse questions of science, but he puts us upon the right road, or at least a path which will take us into the road leading to their solution.

Descartes, the founder of the Deductive method and the father of modern philosophy, in his "Theory of Vortices," gives us his notion of matter and the formation of the universe. "He banishes," says Mr. Lewes, "the idea of a vacuum, because the essence of substance being extension, wherever there is extension there is substance; consequently, empty space is a chimera. This substance is assumed to be divided into equal angular parts, because it is

the most simple, and therefore the most natural supposition. This substance being set in motion, the parts are ground into a spherical form, and the parts rubbed off form a more subtle kind of substance. There is besides a coarser kind of substance. The first kind makes luminous bodies, as the sun; the second the transparent substance of the skies; the third, opaque bodies, as the earth, planets, &c. We may also assume that the motions of these parts take the form of revolving circular currents, or *vortices*. By this means the matter will be collected to the centre of each vortex, while the second, or subtle matter, surrounds it, and by its centrifugal effort constitutes light. The planets are carried round the sun by the motion of this vortex, each planet being at such a distance from the sun as to be in a part of the vortex suitable to its solidity and mobility. The motions are prevented from being nearly circular and regular by various causes; for instance, a vortex may be pressed into an oval shape by contiguous vortices."

Spinoza, who followed Descartes, turned his attention to the *noumenon*, that which lies

beneath all phenomena and produces them—the Substans. This he declared to be God; thus acknowledging the existence of God, but denying the existence of the world.

Leaving Hobbes, "the precursor of modern materialism," and Locke, "the founder of modern psychology," who defines substance as "an unknown support of *known* qualities," we come to Leibnitz. In regard to matter, he held a doctrine of monads very similar to that of Zeno, already mentioned—that matter was composed of mere points without extension.

Boscovich, his disciple, in order to remove the objection which had been made to this doctrine, viz., that a body made up of parts *not* having extension could not itself have extension, held that the points were prevented from touching by a mutual repulsive force existing between them, and thus extension would be produced, this extension producing impenetrability. If, however, the particles were separated a certain distance, they were attracted; if separated farther, they were repelled, and so on. But when the separation was comparatively great, they were continually

attracted, the force then taking the name of gravitation.

Let us for the present dismiss from our thoughts the idealism, scepticism, and sensationalism which are to follow in the train of Locke and Leibnitz, and linger a few moments over this remarkable theory, which appears to the writer to be a rapid stride in the right direction. We have at least something tangible to engage our attention; we may not find it able to solve our problem; but this much it will do, it will prepare the way. Perhaps one of the best methods of getting a correct knowledge of its merits or demerits will be to read one or two honest attacks upon it: the truth can never suffer by them.

Dr. Good, quoted by Dr. Daubeny, thus chastises the philosophic abbé:—"If the monads or ultimate points of matter here adverted to possess body, they must be capable of extension, and consequently of division, as material body under any other dimension or modification; if they do not possess body, then they are as much nonentities as the primal or amorphous matter of Plato or Aristotle. Again,

we are told that these points or monads are endowed with certain powers, as those, for example, of attraction and repulsion. But powers must be the powers of something; what is this something to which these powers are said to appertain? If the ultimate unextended points before us have nothing but these powers, and *be* nothing but these powers, they are powers of nothing, powers without a substratum, and consequently as much nonentities as in the preceding argument. Visible or sensible matter, moreover, it is admitted by Boscovich and his disciples, is possessed of extension; but visible or sensible matter is also admitted to be a mere result of a combination of unextended atoms. How can extension proceed from what is unextended? Of two diametrically opposites, how is it possible that either can become the product of the other?"

"Powers must be the powers of something," says Dr. Good. This is a shoal on which many a valuable ship has been wrecked. The doctor, now, on the supposition that these ultimate unextended points *are* nothing but powers, is

amazed to find that they are powers of nothing —powers without a substratum! They are, then, he declares, nonentities. This is a strange logic. Because powers are discovered to be powers of nothing, therefore these powers —these entities—are nonentities! Why may not one conceive force acting on force to be as good an explanation of a phenomenon as force of matter acting on force of matter? As to Dr. Good's question, "How can extension proceed from what is unextended?" he really must have thought he was posing Leibnitz, for it was to meet that very objection that Boscovich framed his theory.

In regard to the whole of Dr. Good's argument, Dr. Daubeny says: "I confess I do not see the case in the same light; for the merit of Boscovich's system consists in explaining, as far as such a subject admits of being explained, in what manner the idea of extension may arise, from the resistance offered by a number of physical points of matter to the approach of a foreign body; thus showing that the possession of dimensions, as length, breadth, thickness, and consequently of parts, which we

imagine to be implied in the very definition of extensibility, is not altogether inseparable from it. Dr. Good, therefore, takes for granted the point to be proved, viz., that because matter in every shape in which it comes before us possesses extensibility, and consequently parts, therefore the units composing it do the same. Now it was the object of Boscovich to explain that even the idea of extension may resolve itself into something more simple, viz., into resistance to external pressure, and that physical points, even if endowed with powers of attraction and repulsion, might exclude foreign bodies from a portion of space, and thereby produce impenetrability — a property from which, considered under different aspects, result the notions of substance, figure, and bulk.

"Boscovich's theory allows us to maintain in argument the doctrine of particles mathematically indivisible, without enabling our antagonist to convict us of an absurdity, yet it can hardly persuade any one of its reality; and I agree with Dr. Good that the 'lesson taught us by all such fine-spun and fanciful hypotheses is the impossibility of philo-

sophizing without a basis of first principles, without the establishment of certain postulates to be taken for granted in all the subsequent discussion. We must have them in physics as well as in metaphysics, in matter as well as in morals; and hence the best physical schools of Greece, as well as in more modern times, have found it necessary to take it for granted—what in fact can never be absolutely demonstrated—that matter in its ultimate parts consists of solid, impenetrable, and movable particles of definite sizes, figures, and proportions in space; from different combinations of which, though *invisible* in themselves, every *visible* substance is produced.'"

It is remarkable that the very line of argument which was not allowed to Boscovich is here used. If the parts have invisibility, and the whole visibility, why may not the whole have extension, though the parts have non-extension? The senses decide in both cases.

But the whole of this last quotation, in which both the learned gentlemen seem to be of one mind, is unique in its way. "Such fine-spun hypotheses"! What would they say to one

finer spun? And again: "A basis of first principles"! By all means let us have one; and as to "postulates to be taken for granted," why take for granted that "matter in its ultimate parts consists of solid, impenetrable, and movable particles of definite sizes, figures, and proportions in space"? As it was the greatest problem of the "best physical schools of Greece, as well as those of more modern times," to answer the question "What is Matter?" it does seem strange that it should be answered by a postulate taken for granted. "It can never be absolutely demonstrated;" so say the doctors. Have we, however, really come to the end of knowledge?

The celebrated Dr. Priestly, following out Boscovich's idea, maintained that we had no proof that substance was anything more than powers of attraction and repulsion; but unfortunately he was not able to give proof that it was that. But supposing substance to be only powers of attraction and repulsion, it would not follow from this, as Dr. Daubeny seems to imagine, that it could not have "solidity, impenetrability, and the like," even

from his own showing when he took Dr. Good to task.

"The mass of mankind," he thinks, "will be glad to escape from such obscure and abstract speculations, by waiving entirely the mathematical question and confining themselves simply to the inquiry whether it be not most consistent with sound philosophy to admit in a physical sense the existence of atoms, *i.e.* of bodies not destitute indeed of parts held together by a force capable of resisting any natural means which can be brought to separate them."—But in the name of science is this a fair way to deal with the subject? Say "the mass of mankind will be glad to escape from such obscure and abstract speculations," what really has that to do with settling the point? It is only evading it—putting off the evil day. The wisdom of the mass of mankind, on this point, may be profound, their judgment the correct one, but it is a pity that we have no other ground for assurance than the very questionable principle that "it must be right because everybody says so." What did everybody say in the days of Copernicus?

And how does "the mass of mankind" escape? By "waiving entirely the mathematical question"—*that wherein all hope of future success lies*—"and confining themselves simply to the inquiry whether it be most consistent with sound philosophy to admit in a physical sense the existence of atoms," which is in reality going back again to metaphysics!

It may be well to hear the opinion of the illustrious Newton on the subject of atoms, though we have had its main points in the principles of the Epicureans. "All things considered," says Newton, "it seems probable that God in the beginning formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes, figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them, and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break to pieces; no ordinary power being able to divide what God himself made one in the first creation. While the particles continue entire they may

compose bodies of one and the same nature and texture in all ages; but should they wear away or break in pieces, the nature of things depending on them would be changed. Water and earth composed of old worn particles would not be of the same nature and texture now with water and earth composed of entire particles at the beginning. And therefore, that Nature may be lasting, the changes of corporeal things are to be placed only in the various separations, and new associations and motions of these permanent particles; compound bodies being apt to break, not in the midst of solid particles, but where those particles are laid together and touch in a few points." Considering the lustre which attaches to Newton's name, there is a crudeness in his idea of atoms which one does not expect from him who gave us the theory of gravitation.

CHAPTER VII.

WE now come to Faraday, the latest of this world's great philosophers. If any man is able to speak with authority on this subject, it is he. His view will be found to differ widely from that of Newton; but let us remember that two hundred years stand between them — years most fruitful to the cause of Science, wherein she has made such an advance that, had Newton lived at the present day, there might have been no need for such an expression as heads this work.

The views of Faraday are somewhat similar to those of Boscovich, which we have already considered at some length; and he appears to have arrived at such through his researches in electricity, and his seeing the insufficiency of the generally received hypotheses on the na-

ture of matter to meet the results of modern experiment.

The late Dr. Daubeny, though a gifted man and a lover of science, had not sufficient of one quality which marks a true discoverer in science—*imagination*, and unfortunately possessed, I am inclined to believe, too much of another, which has been the greatest barrier to the advance of science—*prejudice*. It is painful to notice how he clings to existing notions, and appeals to common sense. In regard to Faraday's views, he says: "Those who can bring themselves to admit the existence of forces without a something to which these forces belong, and from which they emanate, may very possibly be able to explain the phenomena on Faraday's principles; but my reasons are addressed to that large body of chemists, as well as of unscientific men, who have hitherto recognized the existence of matter invested with certain fundamental properties, as being a notion more intelligible at least, if not more philosophical, than the other."

In a letter to his friend, Richard Taylor,

Esq., after showing that on the ordinary atomic theory the space which is supposed to be between the particles of a substance must be both a conductor and an insulator, which cannot be true, Faraday says: "I am not ignorant that the mind is most powerfully drawn to the phenomena of crystallization, chemistry, and physics generally, to the acknowledgment of centres of force. I feel myself constrained, for the present hypothetically, to admit them, and cannot do without them, but I feel great difficulty in the conception of atoms of matter which, in solids, liquids, and vapours, are supposed to be more or less apart from each other in the intervening space not occupied by atoms, and perceive great contradictions in the conclusions which flow from such a view. If we must assume at all, as indeed, in a branch of knowledge like the present, we can hardly help it, then the safest course appears to be to assume as little as possible, and in that respect the atoms of Boscovich appear to me to have a great advantage over the more usual notion. His atoms, if I understand aright, are mere centres of forces or powers, not particles of

matter in which the powers themselves reside. If, in the ordinary view of atoms, we call the particle of matter away from the powers *a*, and the system of powers, or forces in and around it *m*, then in Boscovich's theory *a* disappears, or is a mere mathematical point, whilst in the usual notion it is a little unchangeable impenetrable piece of matter, and *m* is an atmosphere of force grouped around it.

"In many of the hypothetical uses made of atoms, as in crystallography, chemistry, magnetism, &c., this difference in the assumption makes little or no alteration in the results; but in other cases, as of electric conduction, the nature of light, the manner in which bodies combine to produce compounds, the effects of forces, as heat or electricity, upon matter, the difference will be very great. . . . . All our perception and knowledge of the atom, and even our fancy, is limited to ideas of its powers. . . . . A mind just entering on the subject may consider it difficult to think of the powers of matter independent of a separate something to be called the *matter*, but it is certainly far more difficult, and indeed impossible, to think

of or imagine that *matter* independent of the powers. Now the powers we know and recognize in every phenomenon of the creation, the abstract matter in none; why then assume the existence of that of which we are ignorant, which we cannot conceive, and for which there is no philosophical necessity?

"Before concluding these speculations, I will refer to a few of the important differences between the assumption of atoms consisting merely of centres of force, like those of Boscovich, and that other assumption of molecules of something specially material having powers attached to and around them. With the latter atoms, a mass of matter consists of atoms and intervening space; with the former atoms, matter is everywhere present, and there is no intervening space unoccupied by it. In gases the atoms touch each other just as truly as in solids. In this respect, the atoms of water touch each other, whether that substance be in the form of ice, water, or steam; no mere intervening space is present. Doubtless the centres of force vary in their distance one from another, but that which is truly the matter of

one atom touches the matter of its neighbours. . . . .

"The atom may be conceived of as highly *elastic* instead of being supposed excessively hard and unalterable in form. . . . . With regard also to the *shape* of the atom, and, according to the ordinary assumption, its definite and unalterable character, another view must now be taken of it. An atom by itself might be conceived of as spherical, or spheroidal, or, where many are touching in all directions, the form might be thought of as a dodecahedron. . . . . But if an atom be conceived to be a centre of power, that which is ordinarily referred to under the term *shape* would now be referred to the disposition and relative intensity of the forces. The power arranged in and round a centre might be uniform in arrangement and intensity in every direction outwards from that centre, and then a section of equal intensity of force through the radii would be a sphere; or the law of decrease of force from the centre outwards might vary in different directions, and then the section of equal intensity might be an

oblate or oblong spheroid, or have other forms; or the forces might be disposed so as to make the atom polar; or they might circulate round it equatorially or otherwise, after the manner of imagined magnetic atoms. In fact nothing can be supposed of the disposition of force in or about a solid nucleus of matter which cannot be equally conceived with a centre. . . . . In this view of matter now sustained as the lesser assumption, matter and the atoms of matter would be mutually penetrable. . . . . With respect to the mutual penetrability of the atoms, it seems to me to present in many points of view a more beautiful, yet equally probable and philosophic, idea of the constitution of bodies than the other hypotheses, especially in the case of chemical combination.

"If we suppose an atom of oxygen and an atom of potassium about to combine and produce potash . . . . . if these two atoms be centres of power, they will mutually penetrate to the very centres; thus forming an atom or molecule with powers, either uniformly around it or arranged as the resultant of the powers of the two constituent atoms . . . . .

"The view now stated of the constitution of matter would seem to involve necessarily the conclusion that matter fills all space, or, at least, all space to which gravitation extends (including the sun and its system); for gravitation is a property of matter dependent on a certain force, and it is this force which constitutes the matter. In that view matter is not merely mutually penetrable, but each atom extends, so to say, throughout the whole of the solar system, yet always retaining its own centre of force. This at first sight seems to fall in very harmoniously with Mossotti's mathematical investigations and reference of the phenomena of electricity, cohesion, gravitation, &c., to one force in matter; and also again with the old adage 'Matter cannot exist where it is not.'"

"You are aware," says Faraday in another letter, "of the speculation which I some time since uttered respecting that view of the nature of matter which considers its ultimate atoms as centres of force, and not as so many little bodies surrounded by forces; the bodies being considered in the abstract as independent

of the forces and capable of existing without them. In the latter view these little particles have a definite form and a certain limited size; in the former view such is not the case, for that which represents size may be considered as extending to any distance to which the lines of force of the particles extend; the particle indeed is supposed to exist only by these forces, and where they are it is.

"I suppose we may compare together the matter of the ether and ordinary matter (as, for instance, the copper of the wire through which the electricity is conducted), and consider them as alike in their essential constitution, *i.e.* either as both composed of little nuclei, considered in the abstract as matter, and of force or power associated with these nuclei, or else both consisting of mere centres of force, according to Boscovich's theory and the view put forth in my speculation; for there is no reason to assume that the nuclei are more requisite in the one case than in the other. It is true that the copper gravitates, and the ether does not, and therefore the copper is ponderable and the ether not; but that cannot

indicate the presence of nuclei in the copper more than in the ether; for of all the powers of matter gravitation is the one in which the force extends to the greatest possible distance from the supposed nucleus, being infinite in relation to the size of the latter, and reducing that nucleus to a mere centre of force. The smallest atom of matter on the earth acts directly on the smallest atom of matter in the sun, though they are 95,000,000 miles apart; further, atoms which to our knowledge are at least nineteen times that distance, and indeed in cometary masses far more, are in a similar way tied together by the lines of force extending from and belonging to each. What is there in the condition of the particles of the supposed ether, if there be even only *one* such particle between us and the sun, that can in subtility and extent compare with this? Let us not be confused by the *ponderability* and *gravitation* of heavy matter, as if they proved the presence of the abstract nuclei: these are due not to the nuclei, if they exist at all, but to the force superadded to them; and, if the *ether* particles be without this force, which

according to the assumption is the case, then they are more material, in the abstract sense, than the matter of this our globe; for matter, according to the assumption, being made up of nuclei and force, the ether particles have in this respect proportionately more of the nucleus and less of the force.

"On the other hand, the infinite elasticity assumed as belonging to the particles of the ether is as striking and positive a force of it as gravity is of ponderable particles, and produces in its way effects as great; in witness whereof we have all the varieties of radiant agency as exhibited in luminous, calorific, and actinic phenomena.

"Perhaps I am in error in thinking the idea generally formed of the ether is that its nuclei are almost infinitely small, and that such force as it has—viz. its elasticity—is almost infinitely intense. But if such be the received notion, what then is left in the ether but force or centres of force? As gravitation and solidity do not belong to it, perhaps many may admit this conclusion. But what are gravitation and solidity? Certainly not the

weight and contact of the abstract nuclei: the one is the consequence of an *attractive* force which can act at distances as great as the mind of man can estimate or conceive, and the other is the consequence of a *repulsive* force, which forbids, for ever, the contact or touch of any two nuclei; so that these powers or properties should not in any degree lead those persons who conceive of the ether as a thing consisting of force only, to think otherwise of ponderable matter, except that it has more, or other, *forces* associated with it than the ether has.

"In experimental philosophy we can, by the phenomena presented, recognize various kinds of lines of force; thus there are the lines of gravitating force, those of electro-static induction, those of magnetic action; and others partaking of a dynamic character, might be perhaps included. The lines of electric and magnetic action are by many considered as exerted through space like the lines of gravitating force. For my own part I incline to believe that when there are intervening particles of matter (being themselves only centres

of force) they take part in carrying on the force through the line; but that when there are none, the line proceeds through space. Whatever the view adopted respecting them may be, we can at all events affect these lines of force in a manner which may be conceived as partaking of the nature of a shake or lateral vibration. . . . . It may be asked, what lines of force are there in Nature which are fitted to convey such an action, and supply for the vibrating theory the place of the ether? I do not pretend to answer this question with any confidence; all I can say is, that I do not perceive in any part of space, whether, to use the common phrase, vacant or filled with matter, anything but forces and the lines in which they are exerted. The lines of weight or gravitating force are certainly extensive enough to answer in this respect any demand made upon them by radiant phenomena, and so probably are the lines of magnetic force; and then who can forget that Mossotti has shown that gravitation, aggregation, electric force, and electro-chemical action, may all have one common connection or origin; and so, in

their actions at a distance, may have in common that infinite scope which some of these actions are known to possess?

"The view which I am so bold as to put forth considers therefore radiation as a high species of vibration in the lines of force which are known to connect particles and also masses of matter together. It endeavours to dismiss the ether, but not the vibrations. The kind of vibration which I believe can alone account for the wonderful, varied, and beautiful phenomena of polarization is not the same as that which occurs on the surface of disturbed water or the waves of sound in gases or liquids, for the vibrations in these cases are direct, or to and from the centre of action, whereas the former are lateral. It seems to me that the resultant of two or more lines of force is in an apt condition for that action which may be considered as equivalent to a lateral vibration; whereas a uniform medium, like the ether, does not appear apt, or more apt than air or water.

"The occurrence of a change at one end of a line of force easily suggests a consequent change at the other. The propagation of light,

and therefore probably of all radiant action, occupies *time;* and that a vibration of the line of force should account for the phenomena of radiation, it is necessary that such vibration should occupy time also. I am not aware that there are any data by which it has been or could be ascertained whether such a power as gravitation acts without occupying time, or whether lines of force being already in existence, such a lateral disturbance of them at one end, as I have suggested above, would require time, or must of necessity be felt instantly at the other end.

"As to that condition of the lines of force which represents the assumed high elasticity of the ether, it cannot in this respect be deficient. The question here seems rather to be, whether the lines are sluggish enough in their action to render them equivalent to the ether in respect of the time known experimentally to be occupied in the transmission of radiant force.

"The ether is assumed as pervading all bodies as well as space; in the view now set forth it is the forces of the atomic centres

which pervade (and make) all bodies, and also penetrate all space. As regards space, the difference is that the ether presents successive parts or centres of action, and the present supposition only lines of action; as regards matter, the difference is that the ether lies between the particles, and so carries on the vibrations; whilst as respects the supposition, it is by the lines of force between the centres of the particles that the vibration is continued. As to the difference in intensity of action within matter under the two views, I suppose it will be very difficult to draw any conclusion; for when we take the simplest state of common matter, and that which most nearly causes it to approximate to the condition of the ether, namely, the state of rare gas, how soon do we find in its elasticity aud the mutual repulsion of its particles a departure from the law that the action is inversely as the square of the distance!

"One thing is certain, that any hypothetical view of radiation which is likely to be received or retained as satisfactory must not much longer comprehend alone certain phenomena of

light, but must include those of heat and of actinic influence also, and even the conjoined phenomena of sensible heat and chemical power produced by them."

CHAPTER VIII.

IN Faraday we have come to all that pure science has as yet revealed to us on the question. Before, however, returning to see what Philosophy has accomplished since we left her with Locke and Leibnitz, it will be well to look at some of the modern bearings of the subject. The evidence afforded by modern research goes to prove that the laws of Nature are very simple, that what we considered many forces may be but conversions of one and the same; and it is widely believed that the sixty so-called elements may, when our knowledge has increased, be greatly reduced; "and yet," says Sir Henry Holland, "we shall never prove that there is but one kind of matter, or one nature of force, or that a single law governs all the phenomena around us." This is a bold

assertion, and one which we should take with a great deal of reserve. We must remember that great scientific men—men to whose opinion we should pay great deference—are liable to mistakes. We have an instance in the late Dr. Lardner, who demonstrated scientifically the impossibility of crossing the Atlantic by steam, a noble lord publicly promising to eat the first steamer that performed the feat!

There is one point, bordering somewhat on the metaphysical, but nevertheless an *essential* point in this question, even from a purely scientific view; one which, since the researches of Faraday, will bear mentioning without being scoffed at. It is—as our knowledge of so-called matter is through forces only, whether the matter is not quite an unnecessary adjunct. Faraday says, "We know matter only by its forces." Why not, then, acknowledge that only of which we have knowledge? We know forces; we do not know matter. But it will be argued that the force could not exist without the matter. Can force exist without matter on which to act? Why is force acting upon force not quite as intelligible as force of matter act-

ing upon force of matter? This, then, is the question, and a very important one. Common sense would seem to declare the impossibility. But why should common sense decide the point? As Whately remarks, "Common sense is our best guide only when we have no better." A doctor would navigate a ship by common sense; but a sailor, understanding navigation, would ridicule the idea. The sailor would cure a disease by common sense; but the doctor, understanding medicine, would ridicule such a course. Have we, then, this better guide? There is a question, however, which requires answering before this. Have we ever sought it? Have we not rather laid it down as one of our axioms, as a self-evident point, that there is a something called Matter, and there is a something called Force? It is this taking things for granted that has been so detrimental to the advance of science; so utterly opposed to that philosophy which arose with Bacon, and which we profess to follow.

There are two very remarkable instances of this to be found in any work on natural philosophy. Open any book on the subject, and you

will find two properties of matter taken for granted—impenetrability and porosity. Why should we believe that matter is impenetrable? Because all experience seems to show it. But it may be that things are not what they seem. All experiments show it. But is not that a strange expression of Dalton, that one gas acts as a vacuum for another. Again, why should we believe that porosity belongs to all bodies? Because air or gas can be forced into or through them. But has air or gas ever been forced through glass? When hydrogen escapes from a receiver, who ever thinks it escapes through the glass? And if light, in being transmitted, passes through the pores—as it is asserted, but never proved—then glass ought to be very porous!

In regard to force, considering it as a something acting upon matter, the question has arisen whether force can be annihilated, or even lessened. But this cannot be answered fully till we know whether it is an independent or a dependent something. If independent, then is it not matter itself? If dependent, we ought to know the nature of that upon which it is

dependent, to give a correct answer. Another point is, do we all mean the same when we talk about a force being annihilated? It may appear paradoxical, but the writer can conceive a force ceasing to exist, having not a property, being latent, and yet not annihilated.

There is another of these physical axioms which may be questioned, one which both Professor Faraday and Mr. Grove have attacked with some success. An imponderable ether is supposed to fill all space, interplanetary and interstellar, and to penetrate between the particles of all bodies. The explanation of the undulatory theory of light renders a supposition of this kind necessary, and here we see the necessity for that other axiom, the porosity of all bodies. If it is necessary to suppose that an imponderable something fills all space, why suppose an ether—a substance of which we have no knowledge and can have none? Why create a something? Can we not suppose that plenum to be matter in its original form? Such a supposition would render the existence of an ether superfluous. Because it is matter, it need not convey the idea of grossness to our minds; we

are not unfamiliar with light, heat, electricity, which we *call* imponderable forms of matter. We can suppose this original matter to be imponderable; it will then be ethereal enough to satisfy the most fastidious, if he will not be prejudiced by preconceived notions. But we want something that has none of the properties of matter; that is why we suppose an *ether*, you may reply. If by properties you mean properties of which we can have knowledge by our senses, then why suppose this something which forms the universal plenum to be anything more or less than matter in its original form, having none of the properties of matter of which we are cognizant, and even no properties at all. This original matter may serve several purposes, for some of which *ether* would be unsuitable.

1. It may act simply as a medium, as ether.

2. It may be drawn into the sun and serve as a *pabulum*, by being transformed into the various forms of elementary matter, and furnish light and material for the planets.

3. A generating of original matter may ac-

tually take place during every process of combustion on the earth.

On this point, Sir Henry Holland, in speaking of the physical condition of space, remarks: "Are we to regard this vastness of space as void of matter . . . . .or may we better contemplate it as pervaded throughout by some material medium, though so rare and attenuated that no form of matter of which our senses are cognizant can rightly interpret it to our reason?" A curious question here arises. Taking it for granted that our knowledge of Nature is derived through our sensations, can we by any means have knowledge of this material medium which is "so rare and attenuated that no form of matter of which our senses are cognizant can rightly interpret to our reason?" Sir Henry Holland by his using the word "contemplate" would seem to think not. Though a knowledge of it is not possible to sensation, yet it does not follow that by *reasoning from sensation* we might not succeed.

"The question," continues Sir Henry, "must no longer be argued in that mystical language of 'nature abhorring a vacuum' . . . . nor

can we evade it by the adoption of terms such as *ether*, *ethereal medium*, etc., which though sanctioned by some great names, go little further than to shelter a vague and incomplete solution. Modern science seeks urgently for proof that matter, in some condition, does exist throughout space; and in such continuity, however rare it be, that forces may be transmitted *by* or *through* the medium thus afforded."

A medium having a very extreme tenuity would necessarily have a slight amount of the ordinary properties of matter, as, *e.g.*, resistance; and this has been taken as a reason for the progressive retardation of Encke's comet. The comet however may act like the sun in transforming the original matter it meets in its course, and with which it is surrounded, into ordinary matter, which may go to affect its bulk, and thus produce the retardation.

An argument which might be employed against the idea of a medium of even the most extreme tenuity would be the counteracting effect of such in regard to the gravitating of one body towards another, especially when the

bodies are at a very great distance from each other. Take as an instance the circumstance which led to the discovery of Neptune. Uranus, 1,800 millions of miles from the sun, was found to be disturbed in its movements by a body about its own size 1,200 millions of miles beyond!

On the other hand, an argument which might be employed against the idea of a vacuum in the interplanetary space may be obtained from a remark of Sir John Herschel, who is of opinion that the sun is in a continually excited electrical state, which may account for the tails of comets being always directed away from the sun. Electricity not acting through a vacuum, if he is correct, there must be a plenum. But this loses a great deal of its force, as that which produces the plenum is ether; but when a vacuum is produced by experiment, it is always supposed that the vacuum is a plenum so far as the ether is concerned, for no pump has ever been constructed which touched that point; and in fact if the vacuum be not a plenum of ether, what becomes of the undulatory theory, for light passes through a vacuum, as is very

clear, or we should not be able to see a light on the other side of the receiver, and it must on that theory have ether to be set in vibration. And if we suppose the vacuum to be a plenum of ether when the air is removed, we have had two plena occupying the same space, which surely is not orthodox; and if it be argued that the ether was hidden in the pores of the air, how is it that this ether contrived to stay behind when the air was driven out? If then every vacuum must be a plenum of ether, as the undulatory theory requires, and electricity will not pass through such a vacuum, it seems clear that light and electricity differ greatly, for it appears that electricity requires *ordinary* matter for its medium, but light not. May not then electricity be regarded as a sublimating of ordinary matter, and light such matter sublimated? for electricity produces light, but it does not appear that light must necessarily produce electricity. Altogether what with plena and vacua and ether, the subject is in as highly organized a state of confusion as the bitterest opponent of the undulatory theory could wish for.

Sir Henry Holland has given forth some pregnant remarks on the constitution of atoms. He says: "While, however, even imagination utterly fails to reach the reality, reason accepts this next to infinite divisibility of matter, and the conception of polarities and mutual relations of atoms so constituted, as the sole method of expounding the phenomena. . . . . There is very strong evidence that these molecules of matter, beyond conception though they be, are endowed individually with axes of motion or polarities, determining their mutual relations and the changes they undergo when submitted to forces from without. . . . . The time may come when molecular forces or affinities, now represented chiefly in chemical actions, may be reduced to a common principle with what we term *mechanical forces*. And if gravitation be ever submitted to some common law, with other powers, such law will probably be founded on the nature and functions of these ultimate particles, the materials on which modern science works, amidst the most profound mysteries of the natural world. . . . . The whole science and exquisite art of photo-

graphy in the relations it establishes between light and molecular changes, gives further evidence that these changes form what may justly be deemed the *substratum* of all physical knowledge."

And yet Sir Henry hangs religiously to the old faith, which repudiates all possibility of ever knowing *noumena*, for in speaking of "the old problem of Materialism," he says it is "a controversy equally fruitless in all time to come, since no human conception can reach the abstract nature either of matter or mind; nor any argument show that things perceived by the senses have more independent reality than the principle perceiving, and the intelligence and volition acting upon them."

CHAPTER IX.

LET us now return to Philosophy, and see what she has effected since we left her with Locke and Leibnitz. Following Locke came Berkeley, of whom Byron wrote:—

> "When Bishop Berkeley said 'there was no matter'—
> And proved it—'twas no matter what he said."

Thus was he misunderstood—thus misrepresented.

"If by matter," says Berkeley, "you understand *that* which is seen, felt, tasted, touched, then I say matter exists: I am as firm a believer in its existence as any one can be, and herein I *agree with the vulgar*. If, on the contrary, you understand by matter that occult *substratum*, which is *not* seen, *not* felt, *not* tasted, *not* touched—that of which the senses do not, cannot inform you—then, I say, I be-

lieve not in the existence of matter; and herein I differ from the philosophers, and agree with the vulgar."

Berkeley believed in *phenomena*—denied the *noumenon*. The writer has no hesitation in saying that he was wrong in denying the existence of this *substratum, because it was affirmed to be unknown and unknowable.* What authority has he for saying that it is unknowable? Locke, who believed in the existence of this unknown substratum, held that the nature of it must be for ever hidden from us. Berkeley starts with this: he admits, for the sake of argument, that a *substratum* exists, then—and here was where he went astray—takes it as true that its nature must be for ever hidden from us, and, from this, argues thus: "If it is unknown, unknowable, it is a figment, and I will none of it; for it is a figment worse than useless; it is pernicious as the basis of all atheism." Admitting for a moment that the substratum is unknowable, how does it follow that it must be a figment? But what Berkeley ought to have done was this: he should have demanded *proof* that the substratum was un-

knowable, and that until he had the proof he could not, and would not, advance a step. But even if such proof had been given, Berkeley would then have gone wrong, as he indeed did. He erected a superstructure on a supposition, his foundation-stone was an "if," what wonder then that the edifice remains untenanted, that none will trust themselves within it; and if you ask them why not? they cannot answer other than that they fear some storm shall come and bring it to the ground. How Philosophy erred here! What service might not Science have rendered, had she but stepped between Locke and Berkeley, and said:— "Gentlemen, to advance one step beyond is folly; let us acknowledge that the road terminates abruptly at the entrance of a forest, which, if we do not enter by the right path, we cannot expect to safely traverse; better tarry here with plenty, than perish in the wilderness! Let us endeavour to know this substratum in its *essence*, or prove that it can never be known, and not rest until we have effected either; and let us not be influenced by those professing to be wise, who will tell us we seek the impossible."

But, perhaps, after all, Berkeley would have believed in the *noumenon* had philosophers not contended for that matter which is gross and inert. It may be that, had it been asserted that the *substratum* for which philosophers contended was nothing but *force*, Berkeley would have granted the point; for he was unable to see how matter and spirit could act upon each other, so distinct from each other, not having one property in common. He held that the Creator created laws alone, that these acted upon us directly, without the aid of matter, producing ideas; there was therefore but one substance—Spirit.

Had Berkeley conceived matter to be but force, he would then, probably, have been able to believe in the existence of the substratum, while at the same time holding that there was only one substance—Spirit. What, indeed, is the meaning of that, where he says that matter is inferred by philosophers to explain the phenomena of perception, *i.e. the phenomena of the thinking substance?* Berkeley held that objects did not exist *per se*, that if mind were annihilated, objects would go with it. His opponents

—on this point, mankind generally—denied that such was the case. Now, if they could have been brought to believe that mind was but a manifestation of matter, and matter but force, they would have been able to see the truth of his remark. But Berkeley did not present it to them in this way.

"Berkeley," says Mr. Lewes, "failed as a metaphysical Copernicus, because the assumption which he opposed to the universal belief was less consonant with that belief than the assumption it was meant to replace. Had Copernicus not started an hypothesis, which, however contradictory to the senses, nevertheless afforded a much better explanation of celestial phenomena than was possible on the old hypothesis, he would not have been listened to." "Berkeley," says the same writer, "failed, as the greatest philosophers of all time have failed, not because he was weak, but because Philosophy was impossible."

Following Berkeley came the sceptic Hume, declaring that Mind, equally with Matter, is a figment.

CHAPTER X.

LET us now follow Philosophy into Germany. Here we find Kant maintaining that we have no faculty capable of perceiving things *per se*, it being taken for granted, and beyond question, that our sensibility and understanding are incapable of solving the difficulty. Here, as with Berkeley, we see Philosophy leaving the substance and grasping after a shadow! In regard to the existence of an external world, we find Kant believing in it, but maintaining that it is essentially unknowable; the same bald assertion, asserted generation after generation, century after century, that one gets weary with Philosophy, and longs for Science or something else to come in and prove that it is or is not so. And we have even Mr. Lewes, from whom we might reasonably expect better things, seeing that no one understands more

clearly than he how utterly Philosophy has failed, following her in asserting that noumena can never be positively known.

Suppose one sees embedded in a slab of marble what appears to be the face of a watch, having hour, minute, and second hands; a ticking sound is heard, corresponding in time with the movement of the second-hand; on further examination, a fixed relation is observed between the movements of all the hands, such that when one hand is moved a certain distance, the others must have moved other certain distances; a striking sound is also heard at regular intervals. What would be the first conviction forced upon the mind? Assuredly, that there are *noumena*, so to speak, underlying the face, producing the phenomena. What would be the second conviction? Assuredly, that a careful study of the phenomena would give an insight into the *noumena*. What, then, would be your surprise as you tarried for a short time day by day, year after year, and saw fresh groups of spectators looking intently upon it, most of whom you recognized as men of genius, and heard them, some asserting that

it was only the *face* of a watch, others that there must be something underneath to produce the movements, but that it is impossible ever to know what that something is! Surprise, indeed! Would it not put you somewhat in the same frame of mind as those Jews of Paul's days, as almost to make you bind yourself with an oath not to eat or drink till you had solved the mystery? And what is the face of Nature? Has it not its hour, minute, and second hands—its fixed relation of movements —its striking the hours? Our whole life is a scrutiny of it—our scientific life a closer scrutiny. When shall we ever penetrate beneath the surface? For this, what is necessary? Nothing, but that we note carefully the appearances—which we have indeed amply done—and exercise our reason; and let those who say that "reason is attempting to operate beyond its sphere" content themselves with asserting; let us be content to labour.

The views held by Kant on the nature of matter are deeply imbued with a "philosophic" spirit, having, as they would necessarily, proceeding from such a mind, an extremely meta-

physical basis. "Kant and his followers," says Dr. Daubeny, "preferred regarding matter as penetrable throughout, and as owing its present condition to the balance between the two forces of contraction and expansion. If the former alone existed, the whole universe would be reduced to a mere mathematical point; if the latter, it would spread itself equally over all space. But, owing to the operation of the former power, matter is compressed to a certain limit, beyond which the opposite force operates with superior energy, and thereby prevents any further contraction.

"When two kinds of matter show an affinity one for the other, it is because they are actually penetrable, and when a perfect solution of one substance in another takes place, both are infinitely subdivided, so that each ingredient is uniformly diffused throughout the mass. It must be confessed that this, the Dualist system, presents but an obscure and imperfect image to the mind; but the more modern German schools of natural philosophy appear to have pushed their opinions much farther, as they endeavoured to explain everything by two forces—

expansion and attraction—of which what is called *matter* was the result.

"This attempt," continues the same writer, "at the complete annihilation of substance, this entire resolution of all the phenomena presented to the senses into the effects of forces, which are not yet admitted to belong to any *substratum*, seems as repugnant to our notions on the one side, as the attempt of Epicurus to explain everything by the mechanical properties of his atoms on the other; and few, excepting those whose minds are in a manner pre-occupied by the dogmas of this philosophy, which from metaphysics once strived to extend its empire into the domain of science, and even into that of natural history, will consider the theory in question established on sufficient evidence to be regarded as an impediment to the reception of truths based upon the more substantial and palpable footing of experiment."

The sequel will show how very near an approach to the truth was made by Kant and the more modern German schools of Natural Philosophy in holding these very heterodox views of the nature of matter.

Fichte, who followed Kant, maintained that the Eternal Will created the world in our minds alone, and that philosophers were wrong "in assuming the existence of two distinct disparate existences, Matter and Mind," there being "only one existence having the twofold aspect of Object and Subject."

Schelling, whom Mr. Lewes calls the German Plotinus, declared that "Nature is Spirit visible; Spirit is invisible Nature; the absolute Ideal is at the same time the absolute Real." He believed all matter to be originally liquid; and to it belonged two powers, Light, the inward intuition of Nature; Weight, the outward, through which latter "the Attractive and Expansive force, as the immanent ground of the reality of Matter, operates." The law of polarity he held was the law of universal nature, and vegetation and life the result of chemical processes.

Hegel declared that the non-existence—the nothing—exists, because it is a thought. "The identity of contraries was," he maintained, "the very condition of all existence; without a contrary nothing could come into being.

Being was at the same time Non-Being; Subject, Object; Object, Subject; Light, Darkness; Darkness, Light."

Philosophy seems now to have exhausted itself; like the patriarch of old, it gathers up its feet into the bed and expires. Let us for a moment glance at its last effort—Eclecticism. "Eclecticism," says Mr. Lewes, "means the bringing together of all discovered truths, eliminated from their accompanying errors; and out of this body of truths a doctrine is to be elaborated." A work surely worthy of all commendation, but one that Philosophy was never destined to accomplish. Where she failed was in not knowing the criterion of truth, "even supposing," says Mr. Lewes, "it to be granted that there is *some* truth in all systems."

"Le roi est mort! vive le roi!" Philosophy is dead! Science reigns! Let us see what is the aim of Positive Science as exemplified in Comte, who strenuously maintains the futility of all inquiry into causes and essences. It is that the mind should "apply itself to the observation and classification of *laws* which regulate

effects. . . . and to represent all phenomena as the various particulars of one general view." A very worthy pursuit, but only one-half of Science's legitimate work.

CHAPTER XI.

IT will now be our object to review the whole of the theories in Philosophy and Science, both ancient and modern, and apply to them a process of Eclecticism, selecting those portions which appear to be suitable as materials for the formation of a theory comprehensive enough to grasp all the great problems—except the demonstration of the existence of God, as fruitless as it is foolish—which have occupied mankind; a work, if rightly done, equal in importance to the discovery of a New Method, of which says Mr. Lewes, "Whoso discovers a path whereon mankind may travel in quest of truth, has done more towards the discovery of truth than thousands of men merely speculating. What had the observation and speculation of centuries done for astronomy before the right path was

found? And if a method could be found for Philosophy—if a path of transit from the phenomenal to the noumenal world could be found—should we not then be quickly in possession of the truth?"

If the word "Science" be substituted for "Philosophy," the truth of the above is in no way invalidated. "But," says some one, "we want a criterion of Truth by which to decide what is correct, what not." That, the writer submits, we now possess, by the help of which we learn:—

I. That there is a single original element out of which all things are formed.

II. That this original element need not necessarily be gross matter.

III. That Matter consists of indivisible atoms.

IV. That these atoms do not require nuclei as well as forces, since the forces are sufficient to explain all phenomena, and therefore the atoms may be supposed to be simply forces.

V. That the different elementary atoms are essentially but modifications of the original atom of spherical shape.

VI. That these atoms have axes of motion and poles.

VII. That two forces—Attraction and Repulsion—are sufficient to explain phenomena.

VIII. That these two forces always co-exist.

IX. That atoms are then simple spheres of these two forces, Attraction and Repulsion.

X. That all bodies are known to us by the sensations they produce within us, and these sensations depend upon the particles and their relative positions.

XI. That the World is the resultant sphere of all the atom-spheres comprising it, as gravitation is the resultant attraction of all the particles.

XII. That the Universe is the resultant sphere of all worlds, and is therefore essentially only the existence of two forces, Attraction and Repulsion.

XIII. That matter acting on matter is force acting on force, giving a resultant force.

XIV. That finite Mind is essentially such a resultant force.

XV. The most important of all, even though

it cannot boast of one philosopher or physicist, either in ancient or modern times, as authority, viz.: That a careful study of *Phenomena* reveals the nature of *Noumena.*

PART II.

CHAPTER I.

WE have seen how the mind of man, struggling through the mists and gloom of that ignorance which has now for nearly six thousand years enveloped the human race, earnestly longed to satisfactorily answer this question; how it has framed theory upon theory, system upon system, and all to avail nothing; how it has, as if by some inherent power of intuition, which can manifest itself only in proportion as it is allowed to, seemingly, set ordinary experience and common sense at defiance, taking flight from this hard world of facts and formulæ to that of imagination, whose boundaries are infinite in time and space, declared

what nevertheless must be the true answer, that that which we call *Matter* is but Force, and all the varied phenomena in the wide Universe but manifestations of Force.

But what was the effect of such knowledge upon man—upon even those who claimed to be considered shining lights to their fellows? They would none of it; it was contrary to all they had been taught, contrary to all they thought, and the few who were willing to accept it would not, unless it could by the clearest proof be established. For this Metaphysics was helpless; Physics, some even dared to hope, might put it beyond doubt, but the hope generally died in the conception.

There are some candid enough to feel that a proof that Matter in the ordinary acceptation of the term does not exist, which would stand the test of experiment,—however much it might tend to overthrow the general belief,—ought to be taken as decisive; but the majority set their faces as a flint against every explanation which does not confirm pre-existing notions.

It is to be hoped that those of the former who

read these pages will find the proof herein satisfactory; that those of the latter may for a while lay aside their prejudices, to return to them should they be still unconvinced.

CHAPTER II.

IT is my object to trace, if possible, from the phenomena presented to us, the rise and development of that great work, the Universe; and I trust that the plan which I am about to lay before the reader will not be found wanting in that mathematical precision which is the great desideratum in the establishment of a theory, especially in this matter-of-fact age. If I should fail in applying the rule and compass to the Universe with that exactitude which a rigid geometrician would require, it is I trust only because man is unable to physically grasp creation; but though the infinitely great is beyond our reach, we have the infinitely small in our power, to which it may be possible to apply the simplest principles of geometry and mechanics in such a way as to

demonstrate not only the existence, but the shape, size, internal constitution and essence of ultimate atoms—atoms which are invisible to the eye of sense, and which it seems probable must for ever remain hidden from view.

If I shall ask the reader to accompany me in legitimate inference in regard to the Universe on the one hand, and the original element on the other, I shall not be asking more than would be required in handling any other subject whatsoever, provided only I clearly establish the premisses necessary for a logical inference; for, to use the words of Huygens, "to reason from what we see and are sure of, to what we cannot is no false logic." It is well, too, for the reader to bear in mind the words of Professor John Playfair that—"in all the physical inquiries where mathematical reasoning has been employed, after a few principles have been established by experience, a vast multitude of truths, equally certain with the principles themselves, have been deduced from them by the mere application of geometry and algebra. In mechanics, for example, after the laws of motion were

discovered, which was done by experiment, the rest of the science to a great extent was carried on by reasoning from those laws, in the same manner that the geometer makes his discoveries by reasoning on the definitions, by help of a few axioms, or self-evident propositions."

In the beginning—whenever that may have been—the Supreme Being created the Universe, which is the visible creation.* That the Universe, however vast, is not infinite, I hold, and shall in the proper place endeavour to prove: let it be sufficient for the present to admit it.

The Divine Mind caused a certain immense but yet finite portion of space to be marked off from His immediate presence as a centre—a great sphere of space. This by some manifestation of His power and presence, was filled with centres of force—the seeds, as it were, of that which was to be known as Matter—round each of which two forces, attraction and

* I need scarcely say that the reader is not asked to accept my theology.

repulsion, were in abeyance. It is impossible, except by a process of reasoning, to arrive at a certain knowledge of this something which trespasses upon the territory of the nothing—this entity which verges upon non-entity.

A calling into action, and therefore into existence, of these two forces which lie hidden round each centre—a process which I believe to have taken place by the original element being made to revolve upon an axis—would result in the appearance of the Universe in its first stage of existence, presenting to an eye placed far removed from it in space the appearance of a nebulous cloud. The almost infinite pairs of forces in this mass of original matter would give two resultant forces—a great sphere of attraction and a great sphere of repulsion, and the atoms having a west-to-easterly revolution about their axes, the whole mass would be, as it were, an immense resultant atom, revolving in the same direction. This nebulous revolving cloud would be but the resultant of an almost infinite number of small revolving nebulous clouds, each being the uncondensed matter of a Solar system.

Let us take one of these small nebulous clouds —say that which became *our* Solar system— and observe the changes. A gradual condensation takes place, and, as if to mark the bounds of the system, Neptune is thrown off as an outermost landmark; further condensation, and Uranus, Saturn, Jupiter, and Mars are formed; then follows the Earth, in dimensions extending to the Moon, with a revolutionary period of 29½ days; then follows a further condensation of this nebulous matter, and Venus and Mercury appear; and it may be that there is another nearer still to the Sun, which we, through the brilliancy or other cause, are unable to recognize.

While this gradual condensation of the Solar system is going on, a similar process is taking place in regard to the planets, which form as it were small condensing systems of their own. Take the Earth as an instance: when separated from the mass of the condensing Solar system it is nothing but a nebulous mass with a diameter extending to the moon; this matter begins to condense, and to mark its boundary a ring is formed, which collects into a globular body—

the Moon. Further condensation produces the Earth.

According to this view, it would appear that while the Earth was undergoing condensation to its present form and state, the Sun and Moon were also undergoing condensation to theirs; and if we suppose that the greater power of condensation of the great mass of the Sun, over and above that of the Earth, is as much above as that of the Moon is below, it might follow that the Sun and Moon would arrive at their respective stages of condensation at about the same time that the Earth had so far cooled down as to be suitable as a habitation for man.

Let the same process be applied to other points in the Universe as centres of condensing Solar systems, and we have, as a resultant of all these, a great globe—a celestial sphere—revolving, the Solar systems composing it being gradually attracted from its poles towards the equator, where we find the greatest condensation made manifest to us in the form of a belt —the Milky Way. What now does modern astronomy appear to show this Milky Way to

be? "The result of Herschel's 'gauge' of the heavens," says the writer of the Sixth Dissertation, in the *Encyclopædia Britannica*, "more than confirmed the suspicions of Wright and Lambert, and demonstrated a remarkable, and, on the whole, a steady law of decrease, from the central zone of the Milky Way, in opposite directions, until we reach two poles, one in the southern, the other in the northern hemisphere, which are the localities poorest in stars. . . . . In a direction perpendicular to the plane of the Milky Way, not only is the paucity of the stars remarkable, but we seem to look out, as Sir John Herschel describes it, into a starless region external to the stratum."

Thomas Wright, of whom mention is here made, was a mathematician who lived about one hundred years ago, and was doubtless the first who gave what may be considered a true explanation of the Milky Way. He held that it was "a projection on the sphere of a *stratum* of stars, in the midst of which our sun and system are placed—somewhat eccentrically, however, towards Sirius." As to its constitution, he maintained that it was "a congeries of

stars of a particular form, which it owes to a rotation of the whole round some central point."

It would appear, then, that observation goes to show that the condensation of stars decreases gradually to two points 90° from the Milky Way, around which there appears to be a space, either destitute or nearly destitute of stars. If my view of the Universe be correct, it will, I conceive, follow that for a certain distance around the Galactic poles there exists a space devoid of any stars whatever; for that power which causes the greatest condensation round the equatorial region of the Universe will act in drawing the Suns and systems away from the poles; that power is rotation, and the condensation varies with it; the one being a measure of the other. If the diameter of this small circle of space around each pole could be accurately determined, it would be no difficult task to discover the thickness of the *stratum* of the Milky Way.

Towards the close of the book, the reader will be enabled to draw this as an inference from premisses quite independent of anything that Astronomy may have added to our knowledge.

CHAPTER III.

I WOULD here remark, as clearly a deduction from this mode of viewing the Universe, that there is no need for the projectile force which Newton assumed was given to each of the planets, when they were at their creation sent spinning from the hand of their Creator. It had long been a matter of doubt with me as to Newton's explanation being the satisfactory one—not that I ever doubted the power of the Creator to act in such a way, that is, to create the planets and then project them into space—but it appeared to me that God had so endowed matter that it would act according to laws, in following which it would be as unerring as animate creation in its instincts; and that while I would fully acknowledge His maintaining power and supervision throughout the

Universe, I need not necessarily suppose that this would consist in any individual or special acts, as in His projecting the planets into space. Again I felt a difficulty here: Why should we suppose the planets, which revolve very nearly in circular orbits, to have a path and velocity the resultants of two forces, one gravitation or attraction, *inherent* in Matter; the other, the centrifugal force, *no part* of its constitution. These two forces—the centripetal and the centrifugal—I thought, judging from appearances, must be not only equal in power, but opposite in effects, and both *inherent* in Matter; but there seemed to be no way out of the difficulty, and to fly in the face of Newton, without at least plausible evidence that he was wrong, would be to lay oneself open to the charge of being either a madman or a fool. I confess, too, that I admired Newton's candour in thus acknowledging the hand of the Creator when so many of the same craft either begin or end their labours by ejecting Him from His Universe; and though I felt that I could believe Newton's explanation to be incorrect, and yet not detract one iota from the attributes

of the Creator, I was content to be silent, that those who had declared the Universe to result from "the shuffling concourse of atoms, or to be without beginning," might not have a seeming advantage. But when, upwards of two years ago, I was led to a definite knowledge of the nature of an atom, wherein I saw the manifestation of *one* law, resulting in two equal and opposite forces, attraction and repulsion, I immediately felt that the world is but the resultant of atoms—a great atom of Attraction and Repulsion, and the Universe but the resultant of all worlds,—itself also, as it were, an atom of these two forces, attraction and repulsion, the manifestation still of *one* great law.

But still the reader will doubtless feel that I have not tackled the great difficulty after all; that is, how do the planets revolve round the Sun, or what is the origin of the centrifugal force? It will be remembered that I stated that our Solar system was very probably at first nothing but a nebulous mass of atoms. Now each of these atoms being in its nature a compound of two forces, attraction and repulsion—the one centripetal, the other centrifugal,

—and having a motion from west to east upon its axis, the resultant of all would be a nebulous mass revolving on its axis in a west-to-easterly direction, undergoing condensation.

As condensation proceeded, the inner portion of the mass would acquire a greater velocity, and the outer portion would be left behind in the form of a ring, *but still revolving round the centre of the mass;* this ring, finally, would form into a globe, and while it has a revolution round its own axis, due to the resultant of the forces of its individual atoms, it has also a revolution round the mass of which it forms a portion, *as if it were only an atom.* And we can no more conceive that atom-globe ceasing to revolve round the common centre as a constituent part of the whole mass, than we can conceive such a mass to have an existence and revolution round its axis, if there are no particles to compose it.

What I have said here as to the formation and revolution of the outermost or first-formed planet, would apply to all the members of the Solar system, and, indeed, to all the Solar systems, as but particles composing the Universe.

CHAPTER IV.

IT is from investigations on the action of Light upon the atoms composing bodies that I shall endeavour to establish the premisses necessary for inferring that the Universe is in revolution; they at least will, I trust, be of the greatest importance.

That the reader may clearly understand this portion of the subject, it will be well that he have clearly before him the main points and arguments in the two great theories of Light, which, for the last two hundred years, have more or less kept the field:—the Newtonian or Corpuscular, and the Huygenian or Undulatory. It is from Sir John Herschel's treatise on Light, acknowledged to be the most masterly on the subject in the English language, that I shall gather the material for this part of my work.

In the Newtonian, "light is conceived to consist of excessively minute molecules of matter projected from luminous bodies with the immense velocity due to light, and acted on by attractive and repulsive forces residing in the bodies on which they impinge, which turn them aside from their rectilinear course and reflect and refract them according to the laws observed."

In the Undulatory, "light consists, like sound, in undulations or pulses propagated through an elastic medium, conceived to be of extreme elasticity and tenuity, filling all space. It is imagined to penetrate all bodies; but in their interior to exist in a different state of density and elasticity from those which belong to it in a disengaged state, and hence the refraction and reflexion of light."

CHAPTER V.

IN the Corpuscular or Emission theory, the particles of light differ from each other in their actual masses or inertia, and also in the intensity of their attractive and repulsive forces; those whose inertia is greatest producing the sensation of red.

"The molecules of material bodies and those of light exert a mutual action on each other, which consists in attraction and repulsion, according to some law or function of the distance between them; that this law is such as to admit, perhaps, of several alternations or changes from repulsive to attractive force; but that when the distance is below a very small limit it is always attracted up to actual contact; and that beyond this limit resides at least one sphere of repulsion. This repulsive force is

that which causes the reflexion of light at the external surface of dense media; and the interior attraction that which produces the refraction and interior reflexion of light.

"These forces have different absolute values or intensities, not only for all different material bodies, but for every different species of the luminous molecules, being of a nature analogous to chemical affinity or electric attraction, and hence arises the different refrangibilities of the rays of light.

"The motion of a particle of light under the influence of these forces and its own velocity is regulated by the same mechanical laws which govern the motions of ordinary matter, and therefore each particle describes a trajectory capable of strict calculation as soon as the forces which act upon it are assigned." The latter part of this statement is clearly wrong, for a ray of light travels in a *straight* line and with a uniform velocity when it proceeds in empty space or a homogeneous medium; and that this may be the case the forces can act at the surface only of the body on which the ray impinges. The statement that "the motion of

a particle of light under the influence of these forces and its own velocity is regulated by the same mechanical laws which govern the motion of ordinary matter" must be qualified. That either of these forces when compounded with the velocity of the particle will give a resultant strictly according to mechanical laws shall clearly appear, but when we come to the application of these laws to *ordinary* matter, the case is greatly altered by the appearance of gravitation, and it is very clear that particles of light are unaffected by this force.

"The distance between the molecules of material bodies is exceedingly small in comparison with their spheres of attraction and repulsion on the particles of light.

"The forces which produce the reflexion and refraction are, nevertheless, absolutely insensible at all measurable or appreciable distances from the molecules which exert them."

On this Sir John Herschel remarks, in reference to the *trajectory*, that it "may be regarded as a kind of hyperbolic curve, in which the right lines described by it, previous and subsequent to its arrival at the surface, are the

infinite branches, and are confounded with the asymptotes, and the curvilinear portion is concentred, as it were, in a physical point." It will be made clear that this ingenious supposition is incorrect.

"Every luminous molecule, during the whole of its progress through space, is continually passing through certain periodically recurring states, called by Newton fits of easy reflexion and easy transmission, in virtue of which—from whatever cause arising, whether from a rotation of the molecules on their axes and the consequent alternate presentation of attractive and repulsive poles, or from any other conceivable cause—they are more disposed when in the former state or phase of their periods to obey the influence of the repulsive or reflective forces of a molecule of the medium, and when in the latter, of the attractive.

"Both in refraction and reflection the velocity of the ray after deviation is the same in whatever direction the ray be incident; viz., in a given ratio to the velocity before incidence; this ratio being one of equality in the case of reflexion."

"The sines of incidence and refraction, or reflexion, are to each other in a constant ratio, viz., the inverse ratio of the velocities of the ray before and after incidence." In regard to reflexion, it makes no difference whether the ratio be direct or inverse, since the velocities are the same; but it is of the greatest importance when applied to refraction, since, the sines being in the ratio of a higher number to a lower, the velocity after refraction would be greater than that before, which is not supported by fact. By the true law it is "the *direct* ratio of the velocities," and applies equally to reflexion and refraction.

"When a ray passes from a rarer medium to a denser its velocity is increased, and *vice versâ*." This is the great stumbling-block in regard to the acceptance of the Corpuscular theory; experiment proving that when a ray passes into a denser medium its velocity is *decreased*.

It is important to note that Newton believed in "the similarity of *form* of the law of force for all media, respecting which," says Herschel, "we can be said to know nothing whatever."

"In the Corpuscular theory a ray of light

means a continued succession or stream of molecules, all moving with the same velocity along one right line, and following each other close enough to keep the retina in a constant state of stimulus." If two hundred of them reached the eye every second—only eight or ten are necessary—they would even then be a thousand miles apart; so that we need not have any fears as to their being inconveniently near to each other, and thus interfering with each other's motions. These particles are so minute that, in regard to weight, "millions upon millions have no effect."

As to the cause of the reflexion of some luminous particles and the refraction of others, Sir J. Herschel remarks that "no theory can be satisfactory which does not render a good account of so principal a fact." Newton's doctrine of fits of easy reflexion and transmission is but a reiteration of a fact, and cannot be called an explanation, for it is required to be explained why the ray was "subject to fits."

"The essential conditions," says Sir J. Herschel, "on which the Newtonian doctrine

of reflexion and refraction reposes are—equality of force at equal distances from the general level of the surface, and the perpendicularity of its direction to that level."

With these "essential conditions," and a considerable amount of ingenuity, Newton and his followers have endeavoured to explain many facts in regard to both reflexion and refraction. The attempt has proved but partially successful; it could certainly not have converted any to the Corpuscular faith. The candid investigator of Nature must ever feel that a correct theory will stand its ground unaided by ingenuity and needless suppositions.

CHAPTER VI.

BUT let us examine the Undulatory theory. Its chief hypotheses, according to Sir J. Herschel, are—

"That an excessively rare, subtle, and elastic medium, or *ether*, fills all space and pervades all material bodies, occupying the intervals between their molecules, and, either by passing freely among them or by its extreme rarity, offering no appreciable resistance to the motion of the earth, planets, or comets in their orbits, and having inertia, but not gravity.

"That the molecules of the ether are susceptible of being set in motion by the agitation of the particles of ponderable matter, and that when any one is thus set in motion it communicates a similar motion to those adjacent to it; and thus the motion is propagated further and

further in all directions, according to the same mechanical laws which regulate the propagation of undulations in other elastic media, as air, water, solids, according to their respective constitutions.

"That in the interior of refracting media the ether exists in a state of less elasticity compared with its density than in vacuo (*i. e.*, in space empty of all other matter), and that the more refractive the medium, the less, relatively speaking, is the elasticity of the ether in its interior.

"That vibrations communicated to the ether in free space are propagated through refractive media by means of the ether in their interior, but with a velocity corresponding to its inferior degree of elasticity.

"That when regular vibratory motions of a proper kind are propagated through the ether, and, passing through our eyes, reach and agitate the nerves of our retina, they produce in us the sensation of light in a manner bearing a more or less close analogy to that in which the vibrations of the air affect our auditory nerves with that of sound.

"That, as in the doctrine of sound, the frequency of the aërial pulses, or the number of excursions to and fro from its point of rest made by each molecule of the air, determines the pitch or note, so in the theory of light the frequency of pulses, or number of impulses, made on our nerves in a given time by the ethereal molecules next in contact with them, determines the *colour* of the light; and that as the absolute extent of the motions to and fro of the particles of air determines the *loudness* of the sound, so the *amplitude*, or extent of the excursions of the ethereal molecules from their points of rest, determines the brightness or intensity of the light."

The reader has already learnt what is the most formidable and fatal objection to the Newtonian theory, viz., that a ray of light on entering a denser medium has its velocity *increased*. He will now hear what Herschel considers a most formidable objection to the Undulatory theory. After stating that, from analogy in regard to sounds of every pitch, on this theory "light of every colour travels with one and the same velocity, either in vacuo or in an homo-

geneous medium," Herschel proceeds: "Now there arises *in limine* a great difficulty, and it must not be dissembled that it is impossible to look on it in any other light than as a most formidable objection to the Undulatory theory. It will be shown that the deviation of light by refraction is a consequence of the difference of its velocities within and without the refracting medium, and that when these velocities are given the amount of deviation is also given. Hence it would appear to follow unavoidably that rays of all colours must be in all cases equally refracted, and that therefore there could exist no such phenomenon as dispersion. Dr. Young glosses it over by calling to his assistance the vibrations of the ponderable matter of the refracting medium itself, as modifying the velocity of the ethereal undulations within it, and that differently, according to their frequency, and thus producing a difference in the velocity of propagation of the different colours; more ingenious than successful. The fact is, that neither the Corpuscular nor the Undulatory nor any other system which has yet been devised, will furnish that complete and satisfactory

explanation of *all* the phenomena of light which is desirable. Certain admissions must be made at every step, as to modes of mechanical action, where we are in total ignorance of the forces; and we are called upon, when reasoning fails us, occasionally for an exercise of faith."

There is, again, the objection in regard to *shadows*. "This," says Sir John Herschel, "has been in a considerable degree overcome, since light does spread itself to a certain small degree into the shadow of bodies, giving rise to *inflexion* or *diffraction*, which is completely accountable for on the Undulatory theory and form in fact its strongest points." If we but compare this "certain small degree" of light-spreading into the shadow with the very intense sound-spreading round an obstacle, we will find the analogy between the methods of propagation of light and sound to be very slight—so slight, in fact, that none but those who are wedded to a particular theory and were hard pressed for an argument would find any analogy worthy of serious attention. The subject of *inflexion* may have a good

explanation on the Undulatory theory; but it may appear that both *inflexion* and *deflexion* will receive an equally good explanation on an Emission theory.

CHAPTER VII.

IT seems clear that neither of these theories can be regarded with satisfaction; let us then endeavour to have a clear statement of what will be required from a theory in which confidence may be placed:—

A true theory must satisfactorily explain

In Reflexion:

1. How reflexion takes place.

2. "The connection of the reflecting power of a medium with its refractive index," which appears from experiment to be an undoubted fact.

3. Why the reflected ray has the same velocity as the incident.

4. Why the reflexion of rays depends on the nature of the medium on whose surface they fall.

5. What is the effect of the surface of the medium which the ray had, just before impinging, left.

6. Why at great obliquities the reflexion is more copious.

7. Whether at a very great incidence all the light is reflected.

8. If so, what is that incidence, and what the law by which it is accomplished.

9. If at the greatest obliquity the reflexion is never quite total, as is asserted—why this may be so.

10. Why this copiousness of reflexion at great obliquities appears to be equally true of all media, whether transparent as glass, or opaque as polished metals.

11. Whether it is true that "when a ray is reflected from the exterior surface of a dense medium placed in air the reflexion is by the action of repulsive forces" alone.

12. How the degree of smoothness or polish of the medium very essentially affects the intensity and regularity of reflexion.

13. How the fact can be explained that the more oblique the incidence of the ray, the

greater may be the roughness of the surface which will give a regular reflexion.

14. Whether in order to explain regular reflexion from a surface polished by art it is correct to state that the reflexion of light could not take place by actual impact of its molecules upon those of the reflecting medium, and that "we must suppose the distance to which the forces producing repulsion extend much greater not only than the size of or interval between individual molecules, but even greater than the minute inequalities or furrows on the artificially polished surfaces of media."

15. Why "when two media are placed in perfect contact—as fluid with solid or two fluids—the intensity of reflexion at their common surface is always less the nearer the refractive indices of the media approach to equality."

16. Why "when they are exactly equal reflexion ceases, and the ray proceeds unchanged in direction, velocity, or intensity."

17. Whether from this it follows "that the reflective or refractive forces in all media of equal refractive densities follow exactly the

same laws and are similarly related to each other, and that in media unequally refractive, the relation between reflecting and refracting forces is not arbitrary, but that the one is dependent on the other, and increases and diminishes with it.

In Refraction:—

18. How refraction takes place.

19. How it is a fact that the refracted ray has a *less* velocity than the incident.

20. How much truth there is in the assertion of the Newtonians that for artificially polished media refraction is not performed *close* to the surface, either wholly or in great part, but that "the greater part by far of the flexure of the ray is performed at a distance, out of the reach of those irregularities, and by the action of a much more considerable thickness of the medium than is occupied by them."

21. How it arises that "no regular refraction can be obtained from surfaces sensibly rough at all comparable to the regularity of their reflexion."

In Internal Reflexion :—

22. Whether, when a ray is reflected from the interior surface of a *dense* medium, the reflexion is by the action of attractive forces.

23. Whether the same does not hold equally of the interior surface of *any* medium, dense or rare.

24. Whether it is true that "in the course of a ray internally reflected, the reflexions may take place in any of the attractive regions, whether within or without the true surface, *i.e.* the last layer of molecules which constitute the medium."

25. How it *must* follow that "when the interior angle of incidence exceeds the *limiting angle* whose sine is $\frac{1}{\mu}$, the internal reflexion is total."

26. Whether the following, as given by Sir John Herschel, is a correct explanation of the phenomena of internal reflexion :—

"Let us consider a ray incident exactly at this, the critical angle, and in the most intense phase of its fits of transmission. Then it will be refracted ; and since the angle of refraction must be just 90°, it will emerge grazing the

surface exactly at the extreme boundary of the outermost region, where all sensible action ceases. Its initial velocity, under these circumstances, in a direction perpendicular to the surface, is barely sufficient to carry it up to this extreme limit, where it is quite annihilated. If, then, we conceive another ray also incident in the most intense phase of its fit of transmission, but at an angle more oblique by an infinitely small quantity, then since its initial velocity at right angles to the surface is less, it will be destroyed before it has quite reached this limit, and the ray will therefore begin to move parallel to the surface, just *within* the last limit to the sphere of its action. Now the last action which the surface exerts, or that force which extends to the greatest distance from it, cannot be otherwise than attractive; for, first, were it repulsive, it is evident that no ray incident externally at an extreme incidence (*i. e.* approaching indefinitely to 90°) could by possibility escape reflexion; and, secondly, no ray on that supposition could emerge from within the medium, without having at its emergence an obliquity to the surface greater than

some finite angle, the last action of the medium being in this case to bend it *out*wards, both which consequences are contrary to fact. Or we may consider the point thus :—Since a ray incident within, at the limiting angle, emerges, if it emerges at all, parallel to the surface, and since every point in the curve described by it previous to the instant of emergence is nearer to the medium than the line of its ultimate direction, it is geometrically impossible that the curvature immediately adjacent to the point of emergence should be otherwise than *concave* towards the medium, and must, therefore, of necessity be produced by a force directed *to* it, *i. e.* an attractive one. Hence the luminous molecule we have been considering will be within the attractive region at the moment when its perpendicular motion is destroyed; it will therefore be turned inwards and be reflected. Those in which the circumstances are most favourable to transmission will reach the exterior attractive region; others in which they are less so will be reflected in some intermediate region; while those which are incident at extreme internal obliquities, or in the

most intense phases of fits of reflexion, will have their courses," such as might be produced by the attraction of atoms more interior.

27. Whether "that the attractive force of a medium on the molecules of light extends to a greater distance than the repulsive, is a necessary consequence of dynamical principles."

28. And even if true, whether Brewster has satisfactorily "applied it to explain a fact of Bouguer, viz., that although water be much less reflective than glass at small incidences, yet at great ones (as $87\frac{1}{2}°$) it is much more so." His explanation being that, "supposing the light to have undergone the *whole effect* of the refracting forces, in both cases before it suffers reflexion, its incidence when it reaches the region of the repulsive forces will have been diminished in the case of glass to 57° 44′, but in that of water only to 61° 5′, and therefore, being incident more obliquely on the water, it ought to be more copiously reflected."

29. How it is "that the *regular* internal reflexion from a roughened surface, even at extreme obliquities, is scarcely sensible, even in cases where the external reflexion at the

same obliquities is perfectly regular and copious," which "would seem to indicate *that the forces which operate the external reflexion of a ray exert their energy wholly without the medium.*"

If, then, a theory can be devised which will answer satisfactorily these leading points in reflexion and refraction—which no theory has yet been able to do,—we may well consider all other points as minor in discussing this important question, feeling well assured that every stone will be found to have its proper place when the building is pronounced complete. Let us carefully lay the foundation—carefully place the foundation-stone; let us erect the pillars and roof our temple in; we can even then afford to rest from our labours, and leave to future generations the ornamentation and decoration, the stained glass and tesselated pavement.

PART III.

CHAPTER I.

THE Universe is filled with centres of force; each centre the centre of a sphere; each sphere a compound of two spheres, having the same centre, one a sphere of attraction, the other a sphere of repulsion.

Each of these compound spherical atoms has the two spheres of attraction and repulsion, of which it is composed, of equal dimensions, that is, they form but one sphere, having neither attractive nor repulsive power, and in this state may form that supposed imponderable, ether.

A compound sphere of *force* of such a character is *an atom of matter in its original*

state; being absolutely imponderable, and having none of the properties of matter, its existence cannot be known by our senses, and it is—so far as they can guide us—a *nonentity*.

It is by the separation of these two spheres of attraction and repulsion, and, therefore, by the calling forth and exercise of their powers by each, that we have the different modifications of matter.

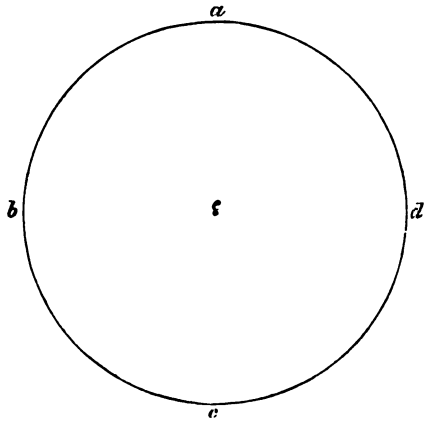


Fig. 1.

Let *a b c d* be one of these atoms of original matter, a sphere which is the limit of two spheres of force, one attractive, the other repulsive, having the centre *e*.

This sphere is, as it were, the meeting-ground of two spheres of force, which increase and decrease together, and at this surface neutralize each other. This sphere then, as it stands, represents an atom of pure and original matter, having a diameter of $\frac{1}{2,000,000}$th part of an inch.

Suppose now that it is required to change this atom of original matter into an atom of,

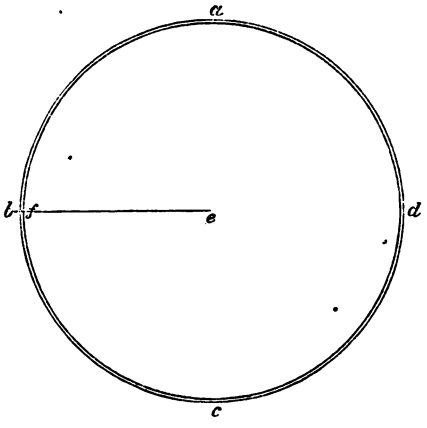


Fig. 2.

say, hydrogen. This is accomplished by separating the two spheres hidden in *a b c d*, so that the distance *bf* between them is equal

to $\frac{1}{3572}$nd part of the radius *be*. This distance *bf* will represent the attractive and repulsive forces, which are always equal; the former acting towards the centre from the point *b*, with a force *bf*; the latter acting away from the centre from the point *f*, with a force *bf*.

Suppose the distance between the spheres, *bg*, equal to $\frac{1}{1852}$nd part of the radius *be*, we have an atom of oxygen.

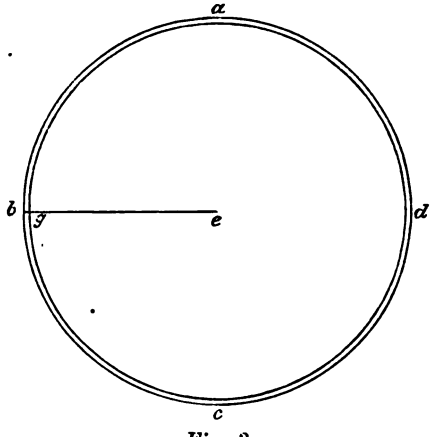


Fig. 3.

Suppose the distance between the spheres, *bh*, equal to $\frac{7}{16}$ths of the radius *be*, we have an atom of water.

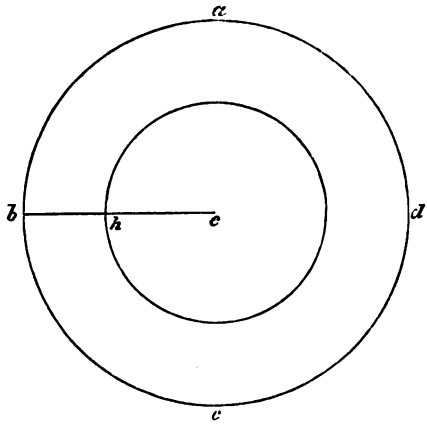


Fig. 4.

Suppose the distance between the spheres, *bi*, equal to $\frac{5}{9}$ths of the radius *be*, we have an atom of glass.

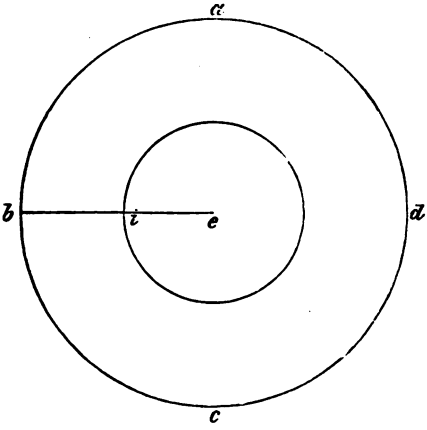


Fig. 5.

Suppose the distance between the spheres, *bk*, equal to $\frac{2}{25}\frac{1}{5}$ths of the radius *be*, we have an atom of diamond.

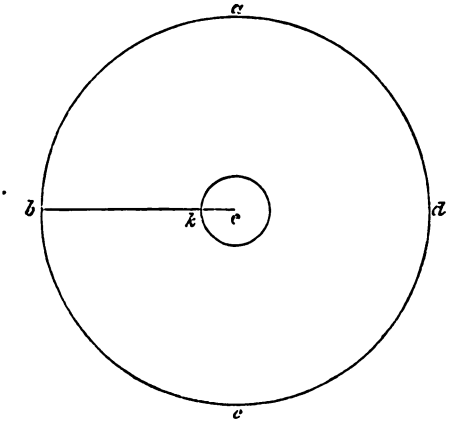


Fig. 6.

Hence it will be seen that the same atom of matter has been successively changed into an atom of hydrogen, oxygen, water, glass, and diamond, by simply causing the spheres to separate more and more, and therefore making the attractive and repulsive forces increase more and more.

It is worthy of observation here that Brewster, in endeavouring to explain the

"persistent activity" of light, remarks that "the ether itself may be a compound body, consisting of, or containing, all the elements of matter."

CHAPTER II.

THE atoms which form the surface of a body undergo the following curious modification:—

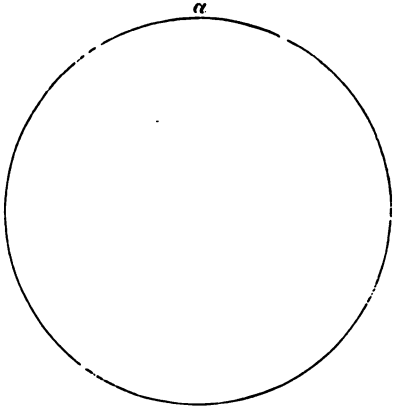


Fig. 7.

As the two spheres in the atom of original matter separate from each other, a break

occurs in their continuity at the highest point (*a*); but the two spheres remain connected by prolongations (*ml* and *on*) from the inner sphere, which it must be borne in mind is the sphere of repulsion.

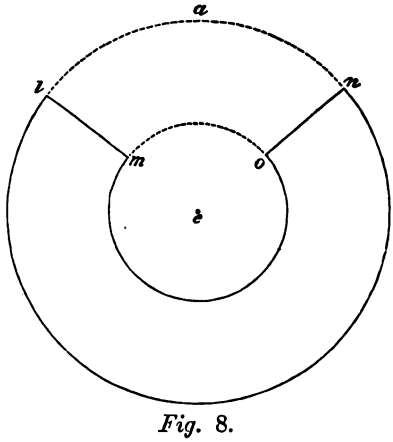


Fig. 8.

Thus a surface-atom of any substance is a combination of two partial spheres of force. Let us suppose a plate of glass; the surface-atoms of the glass will be modified in the above manner, as shown in the annexed sectional view. Those of the interior will be perfect spheres.

The reason for this difference between the

surface-atoms and those in the interior is, that the *latter* are surrounded on every side by forces of exactly the same intensity as their own, in consequence of which, whatever tendency that part of the sphere which is around each pole might have, from its power of revolution, to move towards the equator, is counteracted by the attractive power of the adjacent atoms. But when, as at the surface, we find atoms only partially surrounded by atoms of force of their own intensity, that part which lies, as it were, exposed to the action of other atoms, seems to be uninfluenced by external force, and allowed to follow the action of the force of revolution, and the atom appears as in figure 8.

The surface-atoms alone exert force upon a ray of light passing through a substance, since light, when it enters a homogeneous medium which has its surface-atoms with axes all parallel to each other and perpendicular to the surface, is refracted by these surface-atoms, and then pursues a direct course until it meets the atoms on the other surface, where it undergoes refraction in an opposite direction.

In the case of a thin plate of substance of but one layer of atoms in thickness, the break takes place at both poles of each atom; and the same would hold good of atoms so isolated from each other as to be placed in a medium of a density different from their own.

CHAPTER III.

BEFORE, however, proceeding to prove these statements, I will give a geometrical construction of a surface-atom of water, of glass, and of diamond, as it is on the action of light upon these three substances that I shall mainly depend for the validity of my statements. The figures represent a section through the polar diameter of each atom.

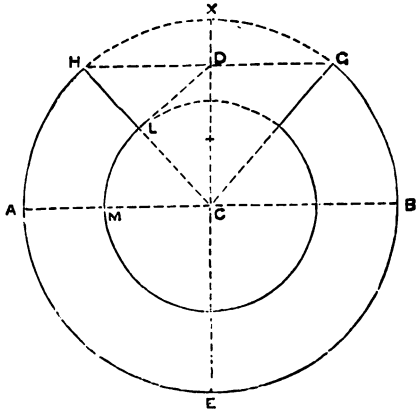


Fig. 9.

A Surface-Atom of Water.

Take any line A B, and from A mark off a portion A C, equal to 4 units, the numerator of the refractive index of water, $\frac{4}{3}$. From C with radius C A describe a circle, X A E B. Through C draw X C E perpendicular to A B, and from C mark off C D equal to three units. Through D draw H D G parallel to A B, meeting the circle X A E B in H and G. Join C H and C G. From D let fall a perpendicular D L on H C. With C L as radius, and C as centre, describe a circle, cutting A C in M. H E G is a surface-atom of water, and it will be found that A C : C D = C D : C M.

Proof:—C H : C D = C D : C L ; but A C = C H and C M = C L ; therefore A C : C D = C D : C M.

A Surface-Atom of Glass.

In figure 10 let A C equal three units, and C D equal two units, the numerator and denominator respectively of the refractive index of glass, $\frac{3}{2}$.

H E G is a surface-atom of glass.

Here also it will be found that A C : C D = C D : C M.

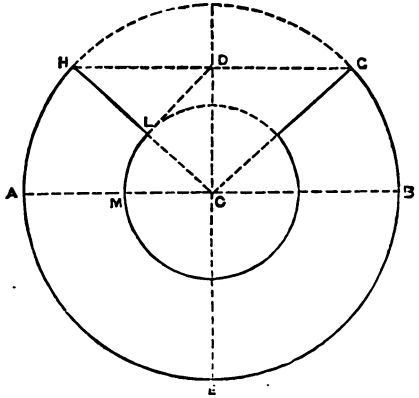


Fig. 10.

A Surface-Atom of Diamond.

In this figure let A C equal five units, and C D equal two units, the numerator and de-

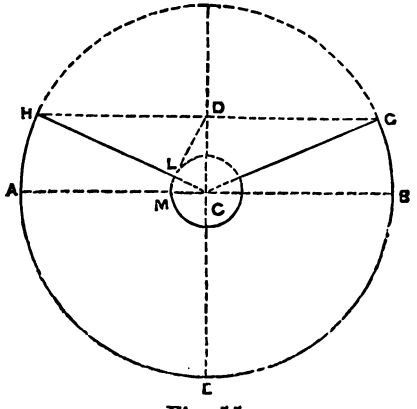


Fig. 11.

nominator respectively of the refractive index of diamond, $\frac{5}{2}$.

H E G is a surface-atom of diamond.

Here it will be found that A C : C D = C D : C M.

The refractive indices of these three substances—water, glass, and diamond — have been given in round numbers as $\frac{4}{3}$, $\frac{3}{2}$, and $\frac{5}{2}$; accurately they are $\frac{1336}{1000}$, $\frac{1535}{1000}$, and $\frac{2487}{1000}$.

CHAPTER IV.

A RAY of light coming from the sun, it is well known, travels at the enormous velocity of 192,500 miles in a second. Such a ray, I conceive, consists of a continuous stream of atoms travelling with different velocities, and at the same time revolving with different velocities upon axes at right angles to their line of projection. These particles are but ultimate atoms of the different forms of matter existing in our solar system, and, though so minute as to be beyond all power of weight, have, I doubt not, a considerable influence in renewing the energy which is being continually expended by our globe. This incessant pouring of millions upon millions of ultimate particles of the elements into our atmosphere, and into even the solid body of the earth, must, I think,

greatly assist in explaining not only the almost universal presence of sodium—doubtless the chief cause of the yellow rays of the sun—but the presence of many other forms of matter which exist to such an extent in the atmosphere that it has been remarked that in a cubic yard of air might be traced the presence of almost every elementary substance. And, again, in regard to the ocean, which occupies three-fourths of the surface of our globe, who can say that the floods of light poured into its depths ages ago, when the sun's power must have been much greater—not to mention its present influence—may not have had a great effect upon its constitution—we know how its temperature is affected—and greatly contributed to the presence of those metals, especially sodium, which are a part of its constitution?

"When a ray of light proceeds in empty space, or in a perfectly homogeneous medium, its course is rectilinear and its velocity uniform, but when it encounters an obstacle or a different medium, it undergoes changes, as follows:—one part is *regularly reflected;* a second and third portion are *regularly refracted.* In many

media these follow the same course, and *perhaps* are in no way distinguishable from each other. In such—comprehending most crystallized substances and liquids—the refraction is *single*. In numerous others—for instance, in most crystallized media—they follow different courses, and retain different physical characters. This refraction is *double*. A fourth portion is scattered in all directions, one part being intromitted into the medium, and distributed over the hemisphere interior to it; while the other is, in like manner, scattered over the exterior hemisphere. These two portions are those which render visible the surfaces of bodies to eyes situated anyhow with respect to them, and are therefore of the utmost importance to vision. Of those portions which enter the medium, a part more or less considerable is *absorbed*, stifled, or lost, without any further change of direction; progressively, as they penetrate deeper and deeper. In perfectly opaque media, such as metals, this absorption is total, and takes place within a space less than we can appreciate; yet even here we have good reason for believing, not *per saltum*. In

crystallized bodies, those at least which are coloured, this absorption takes place differently on the two portions into which the regularly refracted ray is divided. . . . . All those portions which are either regularly reflected or refracted undergo more or less a modification, termed *polarization*, in virtue of which they present, on their encountering another medium, different phenomena of reflexion and refraction from those presented by *unpolarized* light." (Herschel.)

CHAPTER V.

REFRACTION AND REFLEXION.

REFRACTION is a simpler process than Reflexion.

It is the generally received opinion that refraction takes place when a ray passes into the space which separates the atoms of a body. This, however, is, I consider, incorrect; for in order that a ray may be refracted, it must really enter the atom. I trust that I shall be able to clearly establish this, and that refraction does not take place at the actual surface of a body.

Again, in regard to reflexion, some are of opinion with Newton, that a ray of light is reflected without actually coming in contact with the body; others, that mere contact is necessary. I hope to be able to prove the

latter wholly incorrect, and the former *mainly* so, and that in order that reflexion may take place, the ray must *enter* the body; and, moreover, that two atoms are essential to the regular reflexion of a ray. The exception, which makes the statement "that a ray of light is reflected without actually coming in contact with the body" contain a slight measure of truth, I shall farther on employ to establish my theory.

Suppose a ray of light impinges on a surface-atom of a body at the point D (see figs. 9, 10, 11), which I shall call the pole of the atom, it—the ray—is put into a certain state which adapts it for being polarized, or else more or less polarizes it.

What the nature of this state is, and how it really takes place, I am not prepared to say definitely, but that the ray is affected in such a way that it is disposed to be alternately reflected and transmitted, Newton has clearly shown. It may be, in the alternate presentation of like and unlike poles, that the solution is to be found. The true explanation of this subject of the *disposition* of rays to be alter-

nately reflected and transmitted is, I believe, intimately connected with another affection of light, which seems to be shadowed forth in the fact that the rays in passing from one medium into another are in a state quite different from that in which they are while passing through a medium: a state of vacillation or doubt—seeming almost to betoken the workings of a kind of intelligence—as to whether they should proceed into the new medium, remain where they are, or return whence they came. Let not the reader feel startled at this piece of information which I am about to lay before him. The disclosures,—marvellous indeed—which polarization alone has made, ought to convince us that we can rarely be justified in asserting that this or that—however foreign to our notions—is not an affection of light, a subject which seems to abound in marvels, with which we are being every now and then astonished, but, alas, with which we too soon grow familiar, and at last come to look upon as matter-of-course facts. Even the different refrangibility of the rays, which in this age is not regarded with any extraordinary curiosity, was announced

by Newton as "the oddest, if not the most considerable, detection which hath hitherto been made in the operations of Nature." It is well also to bear in mind the words of Comte, that "the phenomena of light will always constitute a category *sui generis*," and that "a light will be for ever heterogeneous to a motion or a sound."

This then I do not hesitate to consider as, perhaps, the most extraordinary conclusion that has ever been arrived at in the whole range of physical inquiry—a conclusion which appears to be so contrary to our experience and knowledge of *motion* that I confess I have felt myself staggered as it has ever and anon risen like a spectre before me in all my researches. I own that I have not hesitated to follow in the way my light has led; that I have in following felt compelled to fling away first this, then that, till I almost doubted the reality of existing things; but here was a point—which I was asked to admit—so contrary to all knowledge, or so eccentric, that it has, I believe, never entered even as a thought into the most eccentrically-speculating brain, that I struggled hard to rid

myself of it. When, however, I saw clearly that it must be indeed an essential part of the theory I was about to advance, I was content to accept it as a fact. It is this: That a ray of light in passing from one medium to another *receives none of its velocity from having passed through the former medium, but on leaving that medium loses what velocity it had, and is, on its entrance into the latter medium, actually without velocity, generating in the new medium whatever velocity it may afterwards acquire.* This velocity being measured by the distance travelled by the ray from the pole of the atom to the sphere of force, and therefore depending upon the angle of incidence and the nature of the medium, being less the greater the angle of incidence, and greater the less the refractive index. But while, as regards the rays that are transmitted, the velocity increases with the decrease of the angle of incidence, the velocity of the rays which are reflected gradually decreases with the angle of incidence—the repulsive force at the same time gradually increasing—until the ray arrives at an angle equal to the complement of the critical angle for the substance, when the

velocity of the rays which are reflected begins to *increase* with the decrease of the angle of incidence, the repulsive force remaining now of the same value throughout. For the present I must ask the reader to take the projectile velocity as I give it in the following investigations.

Suppose then a ray of light impinges on a surface-atom of a body at the pole D (see figs. 9, 10, 11). From this point it passes on in a straight line till it meets with the prolongation of the repulsive sphere acting upon it at some angle less than 90°. When the ray is exactly at right angles to the repulsive force, it forms with the perpendicular an angle equal to the critical angle.

The next ray passes the repulsive force unaffected, and proceeds in its course through the atom. Having passed through, just as it is leaving it comes in contact with the sphere of attractive force, which attracts it towards the centre of the atom. Its onward force—measured by the distance traversed by the atom from the pole to the sphere of force which acts upon it—combined with this force, gives a

resultant retarded force with which the ray passes —if the body be transparent and homogeneous —in a straight line. When it arrives at the other surface, and impinges on a surface-atom, it is acted on by the outer sphere of attraction. The result of which is to refract the ray so that it emerges in the direction in which it was going before it entered the body, and with the same velocity.

CHAPTER VI.

REFRACTION.

WHEN a ray of light falls in an oblique direction upon the surface of a transparent liquid or solid, it is refracted, as is well known—changed in direction by some property residing in the body. It was not, however, known till proved by Snellius, that this refraction was subject to the following definite law:—

That the ratio which the sine of the angle of incidence bears to the sine of the angle of refraction is constant, whatever the value of the angle of incidence, for the same two media, but it is different for different media.

Suppose that A B is the surface of a transparent medium, say water, over which is another medium, air. Let a ray of light, C E,

fall perpendicularly upon the surface of the water; it will suffer no refraction, but pass on in the same straight line E D. Let, however, the ray fall in the oblique direction F E; it

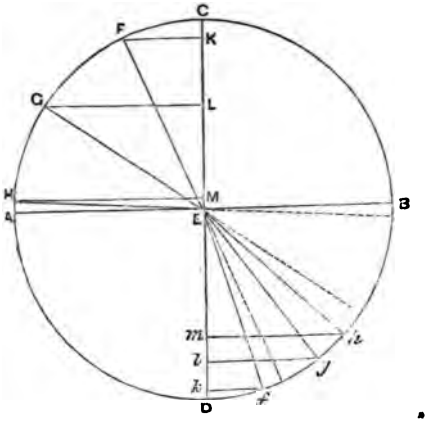


Fig. 12.

will be bent *towards* the perpendicular C D, since it passes into a *denser* medium, and will proceed through the water in the direction E*f*. Similarly any other rays, G E, H E, will be found to pass in the direction E*g*, E*h*. From the centre E, with any radius, describe the circle A C B D. Through F, G, H; *f*, *g*, *h*, the points where the incident and refracted rays cut the circle, draw F K, G L, H M; *fk*, *gl*,

hm, perpendiculars to C D. The perpendiculars F K, G L, H M represent the sines of the angles of incidence; the perpendiculars *fk*, *gl*, *hm*, the sines of the angles of refraction. Now it is known from *experiment* that the sine of the angle of incidence bears to the sine of the angle of refraction a constant ratio. In this case, where air and water are the two media, that ratio is $\frac{4}{3}$; that is, if F K, G L, or H M represents four units, *fk*, *gl*, or *hm* will represent three units. For two different media, as water and glass, the ratio is different. All this is so clearly shown by experiment to be the case, that it stands an indubitable fact. Why it is so, and what is the nature of that property in media which makes it so, has never yet been satisfactorily explained.

Let us see now how these facts of refraction are explained on this theory.

Suppose a ray of light, N D (fig. 13), to fall upon an atom at D, and at any angle of incidence. On reaching Q, it has a velocity which is measured by the distance D Q. As it is leaving the atom with a force Q R, equal to D Q, it is attracted towards the centre C with a force Q S.

These forces compounded give a resultant Q T, to which in every case the original velocity will

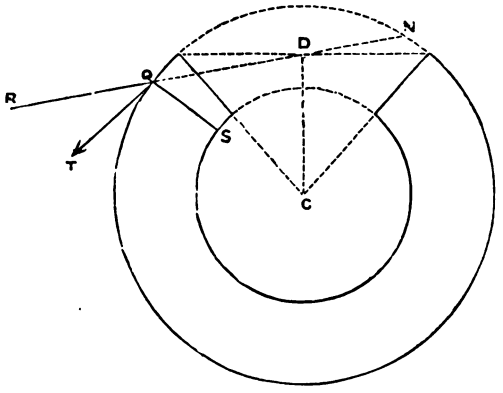


Fig. 13.

be found to bear the ratio of the numerator to the denominator of the refractive index of the medium, as, for water, $\frac{4}{3}$. It will also be found that the rays, as regards direction, follow accurately the law of the sines.

Suppose the ray falls at an angle of incidence F D X, which is the polarizing angle of glass, it will proceed to the point A on the diameter of the sphere, which it will leave with a force A O, equal to A D, being at the same time acted on by the attractive force A M. The resultant of

these two is a force A U, to which the original velocity bears the ratio of the numerator to

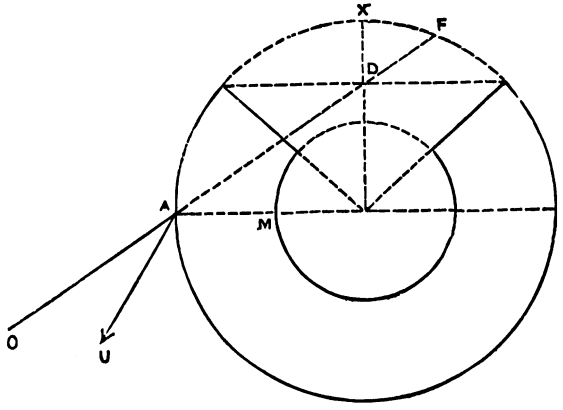


Fig. 14.

the denominator of the refractive index of glass, $\frac{3}{2}$.

Suppose the ray falls at any small angle of incidence, as W D X, upon, say, an atom of diamond, it will pass on to Z, where it will have the force Z O equal to Z D, and the force Z I acting upon it towards the centre. The resultant of these two is a force Z K, to which the original velocity bears the ratio of the numerator to the denominator of the refractive

index of the medium, which is here that of diamond, $\frac{5}{2}$.

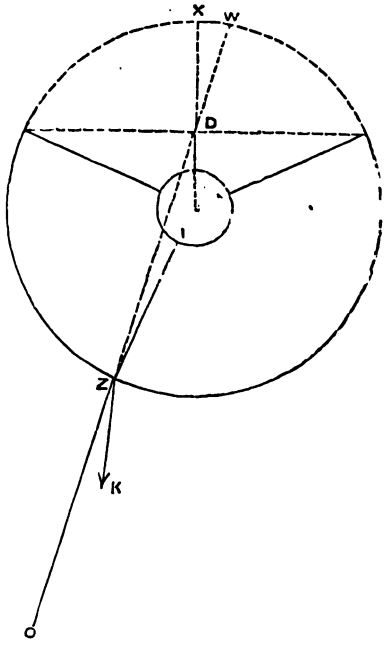


Fig. 15.

In the same way, by taking a ray having any angle of incidence from 0° to 90°, it may be shown that the law of the sines holds good, and that the retardation is the same for all angles, the velocity of the incident ray divided by the velocity of the refracted ray being equal

to a constant quantity—*i.e.* μ of the substance. This, therefore, proves Huygens' *supposition* to be true, that the velocity of light in a vacuum is to its velocity in the refracting medium, as the sine of incidence is to the sine of refraction, *i.e.*, as the refractive index, which is constant. Dr. Young and Fresnel both showed that light was slower in media than in a vacuum.

A ray of light, then, traversing the substance of a diamond, travels with only two and a half times its original velocity. The less the angle of the impinging ray the greater the velocity. So of two refracted rays that which has the greater velocity upon entering the medium will have the greater velocity in the medium.

If the ray is incident at angle 0°, it passes on to E (fig. 16), which it is about leaving with a force E F, equal to D E, when it is acted on by the attractive force P E, towards the centre. The ray is of course not deviated, but simply lessened in speed, the resultant of the two forces being E*a*.

If the ray is incident on D at an angle of 90°, it passes unhindered to H, having at that

point a force H K, equal to D H, where it is acted on by the attractive force H L, towards the centre C. The resultant of the two forces

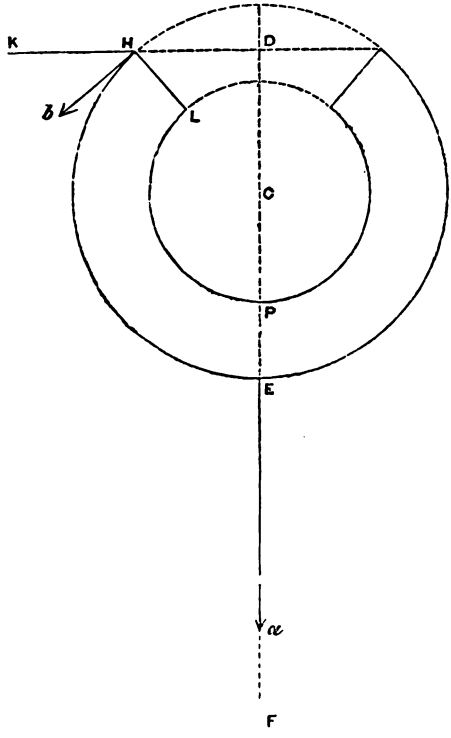


Fig. 16.

is H*b*, which makes, with the perpendicular, an angle equal to the critical angle. Here also we have the law of the sines accurately followed.

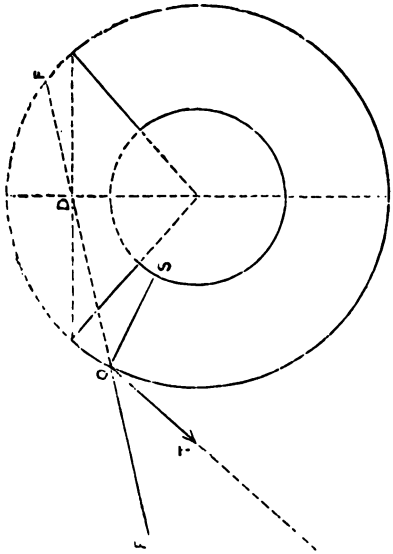
CHAPTER VII.

REFRACTION THROUGH A PLATE OF GLASS WITH PARALLEL SIDES.

WHEN light traverses a medium whose faces are parallel, such as a plate of glass, the emergent ray is parallel to the incident ray. This is evidently caused by a force acting upon the ray when it reaches the second surface, exactly equal to the force which produced the refraction at the first surface, but acting upon the opposite side of the ray. It is because we have such a law operating that we are enabled to see objects through a pane of glass as they really are, with the exception of a slight lateral displacement.

The ray Q R (fig. 17), having been refracted by the attractive force Q S at Q, proceeds with

Fig. 17.



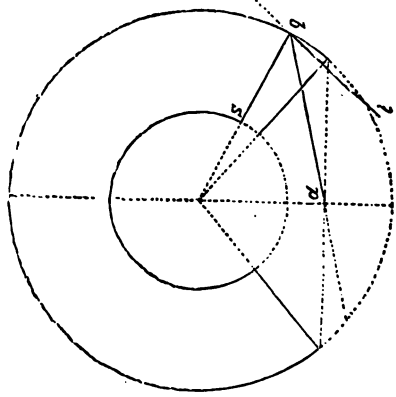
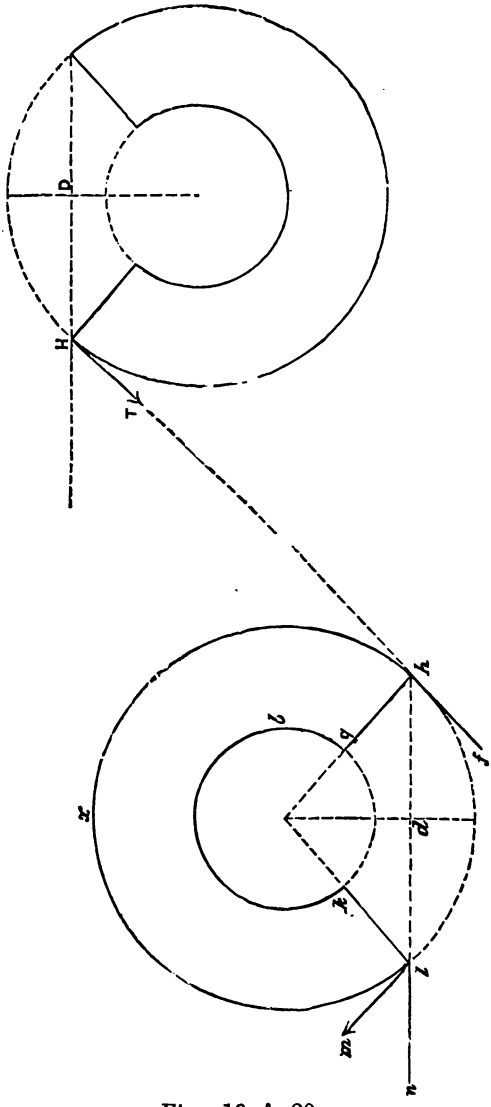


Fig. 18.

retarded uniform velocity in a right line through the glass; and when it reaches the atom on the lower surface (for it appears that the surface-atoms alone exert a force upon it), it is again acted on by an attractive sphere of force. This force *qs*—equal to Q S, combined with *qt* equal to Q T—gives an accelerated resultant force *qd*, which passes through the pole, following the law of the sines. The ray, therefore, emerges in a direction parallel to its original direction, and with its original incident velocity.

Since every ray in its refraction follows the law of the sines, it is clear that the ray, having an angle of incidence 89° 59′, will be so refracted that the sine of incidence : sine of refraction = 4 : 3 for water, = 3 : 2 for glass, = 5 : 2 for diamond; the angle of refraction being in each case a *very little* greater than the critical angle of the substance. Suppose, now, the ray meets the point D (fig. 19) at an angle of 90° with the perpendicular; on leaving H it will be refracted according to the law of the sines, and the angle of refraction will be found to be exactly equal to the critical angle. It is



Figs. 19 & 20.

evident that the refraction in this case must be greater than in any other, since the angle of incidence is greater than any other.

Let the ray proceed through the body to the lower surface, it will meet that surface—which is parallel to the upper—at an angle equal to its angle of refraction. But it is a tangent to the sphere *hlx* at *h*, and at this point is at right angles to the attractive force *gh*, which acts upon it, giving a resultant, *hd*, passing through the pole *d*. The ray passes on to *l*, having a force *ln*—equal to *ld*—where it is acted on by the attractive force *lk*, and taken into the medium again, agreeing with experiment, which tells us that it is wholly *reflected* together with rays of greater incidence, and that all rays of less incidence are refracted according to the law of the sines.

CHAPTER VIII.

CRITICAL ANGLE.

IT has been long known to physicists that when a ray of light passes through a transparent substance and meets the surface at a small angle of incidence, it is refracted according to the law of the sines discovered by Snellius; but on the angle being increased to a certain degree—48° 35′ for water—total *reflexion* takes place.

In the preceding chapter it was stated that the ray which impinged on the upper surface of a transparent body at 90°, on being refracted, passed through the body and met the sphere of attraction of an atom of the lower surface at the critical angle of the substance, and was therefore wholly *reflected*, as experiment has repeatedly shown. But if the law of Snellius

holds in this case, the ray must be refracted according to the ratio of the sines. It will appear that this law does hold good—that the ray is accurately *refracted* and also totally *reflected.*

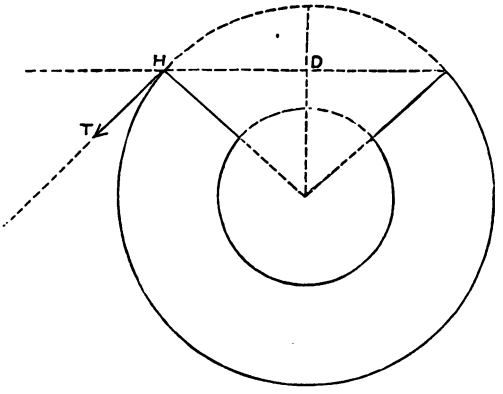


Fig. 21.

It was shown that the ray H T (fig. 19), on reaching *h*, was attracted towards the centre by a force *gh*, which refracted it according to the law of the sines. Similarly it could be shown that every ray falling upon the sphere *lxh*, at any angle with the perpendicular *xd*, from 0° to the critical angle of the substance—at which angle the ray is a tangent to the sphere *lxh*,—is refracted in the same manner, the attracting

force being equal to *gh*. The ray which meets the sphere *lxh* at the critical angle has, of course, the attractive force to the centre *gh*, acting upon it, the result of which is, the ray is refracted according to the law of the sines in the direction *hd*, and is represented in mag-

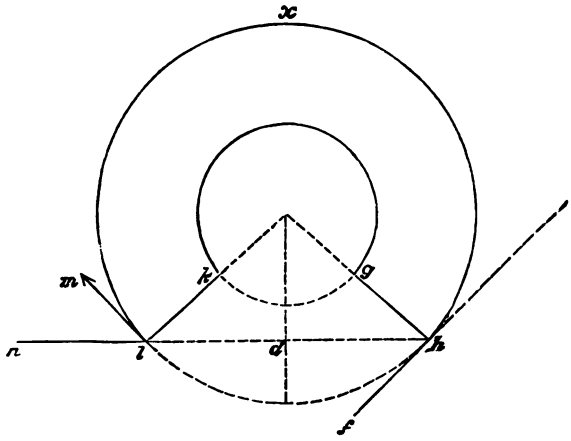


Fig. 22.

nitude by *hd*. But when the ray reaches the point *l*, having a velocity *ln*—equal to *dl* or *dh*,—it is acted on by the attractive force *kl*, towards the centre, acting at right angles to the ray, and is refracted again according to the law of the sines, at an angle equal to the

critical angle, the result of which second *refraction* is, that the ray is reflected.

It thus appears that total reflexion is composed of two refractions, in both of which the law of the sines holds good.

CHAPTER IX.

REFLEXION.

WHEN treating on the subject of Refraction, I stated that it was a simpler process than Reflexion, and therefore described it first. I also stated that the *first* ray was disposed to be reflected, the second refracted, and so on; and partly for this reason: the force which produces the reflexion of the ray is the nearer to the pole, and is therefore that which the *first* ray of light first meets.

To recapitulate a few sentences from the chapter on "Refraction and Reflexion," as they have an application to this part of my subject:—

"Suppose a ray of light impinges on a surface-atom of a body at the point D (*see* fig. 9), which I shall call the pole of the atom, it—the

ray—is put into a certain state which adapts it for being polarized, or else more or less polarizes it. . . . . From this point it passes on in a straight line, till it meets with the prolongation of the repulsive sphere acting upon it at some angle less than 90°. When the ray is exactly at right angles to the repulsive force, it forms with the perpendicular an angle equal to the critical angle. The next ray passes the repulsive force unaffected, and proceeds in its course through the atom" to become the refracted ray.

The first ray is that which, after undergoing two refractions, is reflected, and in the following manner:—

Let the ray N D (fig. 23) impinge on an atom at D; when it reaches F, a repulsive force H F, acting in L H, the prolongation of the repulsive sphere, refracts it so that it proceeds with increased speed parallel to the surface D'H K D, of the medium, being represented by the resultant F I. On reaching the point I, in the next atom, it is acted upon by a similar repulsive force I K, of the same magnitude as the other. The result of which is, the ray is decreased in speed

as much as it was before increased, and passes in the direction of I D′, through the pole D′,

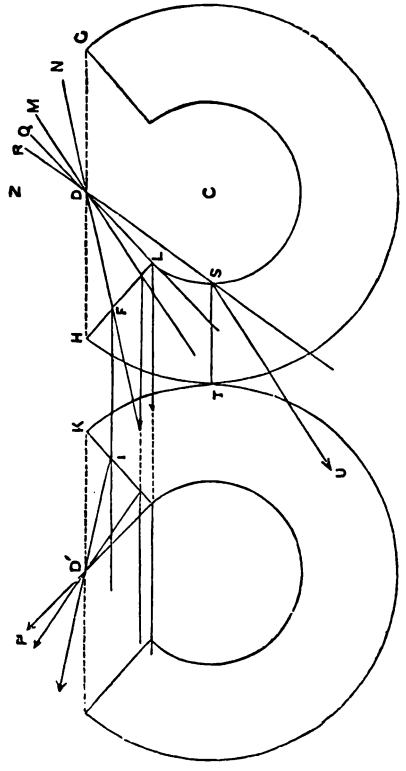


Fig. 23.

and out of the body with the velocity it had on entering, and at the same angle.

If the ray be incident at the polarizing angle—always the ray which if produced would meet the sphere of attraction at its intersection with the equatorial plane of the atom—whatever the medium—it will emerge at the polarizing angle, making the angle of reflexion equal to the angle of incidence.

If the ray be incident upon the repulsive sphere at the point L—that is, at an angle equal to the critical angle for the substance—it will be the last refracted *parallel* to the surface.

Suppose now that the ray is incident at an angle less than the critical angle, as R D Z. On reaching S, it will be repelled with a force S T, giving a resultant S U, the refraction being from the perpendicular and the velocity increased.

It must be borne in mind that this is not properly a refracted ray, although in one sense it is quite as much as any other; but it is a ray which would have been reflected had it not passed below the sphere of repulsion of the next atom. And even then, unless it met that sphere within certain limits, it would not even

be reflected, but driven here and there, perhaps at last to escape as a ray of that light which is reflected from the surface apparently according to no law. It must also be borne in mind that these rays, when traversing a substance, travel with their primary velocity increased. It may be too that some of these rays are absorbed and some also refracted.

It is from these rays that we may expect to learn some additional information about Internal Reflexion and Double Refraction. There seems reason to believe not only that they have peculiar properties but that the inner sphere of the atoms on the interior surface of a medium acts in a reversed manner, not only upon them but upon the ordinarily refracted rays also. In regard to Double Refraction, it is worthy of observation that Laplace held that the extraordinary ray was produced by the action of a *repulsive* force emanating from the axis of the crystal.

CHAPTER X.

MEDIA, DENSE AND RARE.

IN considering the passage of a ray which undergoes total reflexion, it is always taken for granted that the ray, to produce this effect, must pass *from a denser medium into a rarer*. Now I will not undertake to say that this is wrong; but it appears to me that if it is, and I have yet to learn that it is otherwise, since the atoms of the rarer medium are in their *essence* the same as those of the denser, the difference consisting not in the *quality* of the force manifested, but in the *quantity*—whatever property the denser may possess in regard to reflexion or refraction, or indeed any other affection, that property must be possessed—in a less degree I admit, but still in some degree —by the rarer. And indeed, if the reader will

but consider for a moment in how many points the denser and the rarer—take glass and air, which surely are different enough in regard to what is called their chemical constitution to satisfy the most sceptical—agree, say, in such a point as that they both reflect light according to the ordinary law of reflexion, or refract it according to the law of the sines; surely he ought herein to see that such results must follow from the action of some law or laws which belong equally to both. This granted, where is the reason for not recognizing a critical angle as being as much an essential of the rarer as of the denser? Granted, then, that the rarer medium, air, has a critical angle, it evidently will be found in the same way in which that of diamond, glass, or water is found, viz., by computing the angle whose sine is the reciprocal of the index of refraction. In water this is, according to Herschel, arc sin. $\frac{1}{1\cdot336}$, or 48° 27′ 40″; in crown glass, 40° 39′; in flint glass, 38° 41′; in diamond, 23° 42′; in chromate of lead, 19° 28′ 20″. This is when the ray passes from a vacuum. Now the index of refraction of air being 1·00028, the critical angle would be

arc sin. $\frac{1}{1.00028}$, or 88° 38′ 39″. Let us now suppose a ray to pass through the rarer medium —air—on its way to impinge on the glass. It is evident that the moment before it impinges on the glass it may be considered as a ray incident on the *interior* surface of a medium. While the angle which the ray makes with the perpendicular is less than the critical angle, it will be refracted and pass out of the medium according to the law of the sines; and since this angle is 88° 38′ 39″, all, or nearly all, the rays, from the perpendicular incidence up to this great obliquity, pass refracted out of the medium; but all rays which impinge on the interior surface at this angle, and any angle of greater incidence up to 90°, ought to be reflected into the medium again. Herein it appears to me lies the explanation of the great reflexion from *all* smooth surfaces at a very great angle of incidence. It matters not what the substance is,—glass, silver, mercury, steel, ivory, wood, sealing-wax, paper, or anything else capable of having a smooth polished surface imparted to it—if it be held between the light and the

eye, so that the rays impinge on it at a very great obliquity, there will be a brilliant reflexion, which will be found to be total, I believe, if the substance be highly polished. That this reflexion is due to the action of the interior surface of the rarer medium, and in no way results from any action of the denser medium, which acts only in assisting the rarer to procure an even surface, is clear, since the reflexion presents the same appearance, whatever the denser medium may be, white, black, or otherwise coloured, which would certainly not be the case if the rays had in the least degree penetrated the denser.

I am aware that it is held that rays incident on the exterior surface of a medium follow a somewhat different law from that which causes the reflexion of rays incident on the interior surface; but I have, I trust, adduced evidence sufficient to make us question the truth of it. Herschel states the point clearly enough, but it appears to me, overlooks this, that some of those rays which he supposes are incident on the *exterior* surface of the medium are really incident on the *interior* surface of some other

medium, and therefore ought to be supposed to follow the law which produces internal reflexion. He says: "When a ray is incident on the exterior surface of a medium, a portion (R) is reflected, and the remainder (r) is refracted. The ratio of R to r is smallest at a perpendicular incidence, and increases regularly till the incidence becomes 90°; but even at extreme obliquities, and when the incident ray just grazes the surface, the reflexion is never total or nearly total; a very considerable portion being intromitted. On the other hand, when the ray is incident on the interior surface, the reflected portion (R) increases regularly with a very moderate rate of increase, till the angle of incidence becomes equal to the critical angle whose sine is $\frac{1}{\mu}$, when it suddenly, and, as it were, *per saltum*, attains the whole amount of the incident light, and the refracted portion (r) becomes zero." If, however, Herschel means that the ray which impinges on the exterior surface passes through a vacuum, there would be no critical angle, and in that case no proper external reflexion whatever. There would of course be that reflexion which

is produced by the dense medium, the law concerning which I have already considered; that should not be confounded with the true external reflexion. I have not overlooked the fact that the denser medium would assuredly make its superior force manifest in counteracting the weaker force of the rarer medium. The surface-atoms of two contiguous media produce counteracting effects proportional to their forces, for if two media having the same refractive index be brought into perfect contact, there is no reflexion at their common surface; thus showing that the rays are attracted equally by both media, and consequently proceed without deflection.

CHAPTER XI.

REFRACTION FROM ONE MEDIUM INTO ANOTHER.

IN the chapter on Refraction the subject was dealt with only in its relation to a ray passing into a medium from a *vacuum*. We have now to consider the refraction of a ray which has passed from *another* medium. It is a well-established fact that when a ray passes from one medium to another the sine of the angle of incidence on the interior surface of the first medium is to the sine of the angle of refraction into the second medium as the index of refraction of the second is to the index of refraction of the first; that is, if we suppose a ray to pass from water into diamond,

$$\frac{\sin i}{\sin r} = \frac{\mu'}{\mu} = \frac{\frac{5}{2}}{\frac{4}{3}} = \frac{15}{8}$$

And if the ray before entering the water had

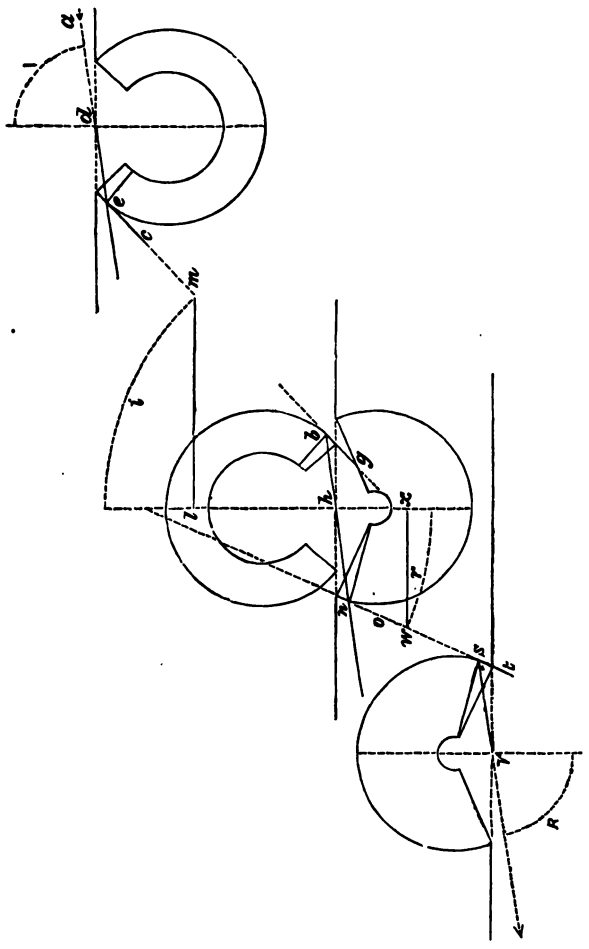


Fig. 24.

traversed a vacuum, or any medium, as air, on emerging from the diamond, it would have the angle of Refraction R equal to the angle of incidence I, which it had before entering the water.

Suppose a ray, *ad*, passes from a vacuum into water, it is refracted in *ec;* on reaching the lower surface of the water it is again refracted in *bh*, in which direction it passes through the pole of the atom of the next medium, diamond, to *n*, where it is refracted in *no*, whence it passes on to the lower surface of the medium, where it is refracted in *sv*, at an angle of refraction R, equal to the original angle of incidence I. It will be found also that the sine of the angle of incidence (*i*) of the ray upon the interior surface of the first medium is to the sine of the angle of refraction (*r*) into the second medium, as 15 is to 8.

CHAPTER XII.

ON THE DIMENSIONS OF ATOMS.

EXPERIMENT has shown that air ceases to reflect light at or below a thickness of $\frac{1}{2,000,000}$th of an inch, or $\frac{12}{24,000,000}$ths; water ceases to reflect light at or below a thickness of $\frac{3}{8,000,000}$ths of an inch, or $\frac{9}{24,000,000}$ths; glass ceases to reflect light at or below a thickness of $\frac{1}{3,000,000}$ths, or $\frac{8}{24,000,000}$ths.

Hence, if an inch be divided into 24,000,000 equal parts, the thicknesses required by air, water, and glass, in order to reflect light, must be respectively 12, 9, and 8 of these millionth parts. Let us suppose now that these are the actual dimensions in thickness of an atom of each of these substances, and endeavour to prove the correctness of this supposition.

We have as refractive indices for—

Vacuum (or Original Element)	1.000000 =	$\frac{1}{1} = \frac{4092}{4092}$
Air	1.000294 =	$1\frac{1}{3410} = \frac{3411}{3410} = \frac{4093}{4090}$
Water	1.336000 =	$1\frac{1}{3} = \frac{4}{3} = \frac{4092}{3069}$
Glass (Crown)	1.500000 =	$1\frac{1}{2} = \frac{3}{2} = \frac{4092}{2728}$

From these construct the atoms as previously described, letting the numerators stand for the equatorial radii, the denominators representing the distance of the pole from the centre.

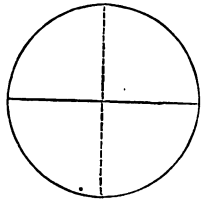


Fig. 25.

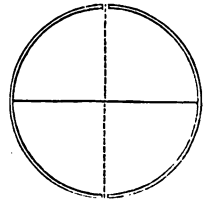


Fig. 26.

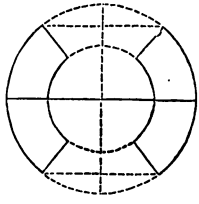


Fig. 27.

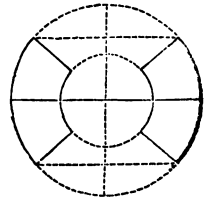


Fig. 28.

The radius being 4092, the diameter will be

8184; the ratio of the semi-axis to the equatorial diameter will be in

Vacuum (or Original Element)	$\frac{4082}{8184}=\frac{12}{24}=\frac{1}{2}$
Air	$\frac{4080}{8184}=\frac{12}{24}=\frac{1}{2}$ nearly
Water	$\frac{3069}{8184}=\frac{9}{24}=\frac{3}{8}$
Glass (Crown)	$\frac{2725}{8184}=\frac{8}{24}=\frac{1}{3}$

But Newton has shown by experiment that the thicknesses required were $\frac{12}{24}$, $\frac{9}{24}$, and $\frac{8}{24}$ millionths of an inch, which are the fractions given in the second column, with the exception of that of air, which is very nearly what Newton gave it. It will easily occur to the reader how Newton came to be thus slightly in error.

But as Newton's experiment gives the actual thicknesses, and our calculations the proportion between the semi-axes, it is only necessary to suppose all the axes of the atoms reduced one half, so that they correspond to the thicknesses, and we have, by combining theory and experiment, a proof not only that atoms exist, but that they can be as accurately measured as if they were so many billiard-balls. What, then, is the exact size of an atom? When, two hundred years ago, Newton said that water ceased to reflect light at a thickness of $\frac{3}{8}$ths of

the millionth part of an inch, he in that unconsciously declared the size of an atom of water.

From the above,

The axis of an atom of the Original Element is		$\frac{1}{2000000}$ in.
„	Air	$\frac{1}{2006882}$ in.
„	Water	$\frac{1}{2666666}$ in.
„	Glass	$\frac{1}{3000000}$ in.

The equatorial diameter of all atoms is the same, viz. $\frac{1}{2,000,000}$th part of an inch.

CHAPTER XIII.

ANGLE OF POLARIZATION.

IT is not my intention to enter into the subject of the polarization of light, on which alone a book might be written; but I cannot help making a few observations on the angle at which light is found to be completely polarized when incident upon different substances, as it results from the action of a law of the greatest simplicity.

The polarizing angle of a substance is the angle which a ray of light makes with the perpendicular to a plane polished surface of a substance upon which it is incident, in order that the polarization may be complete. This angle differs with the substance, being for diamond 68°, for glass 54° 35′, and for water 52° 45′.

The ray which is completely polarized is

always that which would have met the intersection of the sphere of attraction and the plane of the equator, had it not been reflected. Let the reader observe the incidence of a ray upon a surface-atom of each of three substances, water, glass, and diamond, so as to fulfil this condition, and it will be found that the angle of incidence is for water 52° 45′, for glass 54° 35′, and for diamond 68°, as may be gathered from figures 29, 30, 31.

The truth of Brewster's law that "the polarizing angle of a substance is that angle of incidence for which the reflected polarized ray is at right angles to the refracted ray," will be evident from an inspection of the figures, in each of which the angle *aeb* is a right angle.

The light of the atmosphere is polarized, and of course has an angle of maximum polarization. It is the received opinion that this angle is 45°; this, however, I shall show to be incorrect. But I will first lay before the reader a few observations by Professor Tyndall, made in a very recent lecture before the Royal Institution. He says: "The angle of incidence,

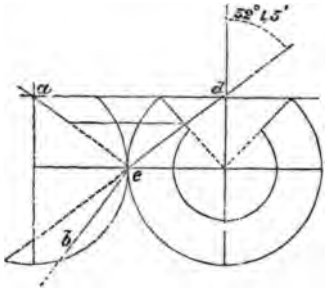


Fig. 29.

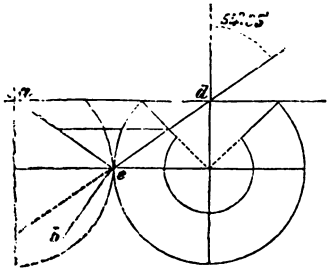


Fig. 30.

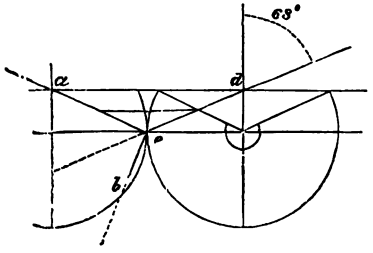


Fig. 31.

which corresponds to the maximum polarization of the sky is half of 90°, or 45°. This is the atmospheric polarizing angle, and the question is, What known substance produces an index of refraction to correspond with this polarizing angle? If we knew this substance, we might be tempted to conclude that particles of it, scattered in the atmosphere, produce the polarization of the sky. . . . . But a polarizing angle of 45° corresponds to a refractive index of 1: this means that there is no refraction at all; in which case we ought to have no reflexion. Brewster and others came to the conclusion that the reflexion was from the particles of air themselves. . . . . It is difficult to affix a physical meaning to this conclusion. If light be reflected, it must be at the common limiting surface of two media of different refrangibility. But to satisfy the law of Brewster, as Sir John Herschel remarks, 'The reflexion would have to be made *in* air upon air!' 'The more the subject is considered,' adds the celebrated philosopher last named, 'the more it will be found beset with difficulties, and its explanation, when arrived at, will probably be found

to carry with it that of the blue colour of the sky itself.' "

Professor Tyndall continues: "This law (of Brewster) leads to the extraordinary conclusion already announced, that the reflexion takes place at the limiting surface of two media of the same refrangibility, where reflexion could no more occur than it could occur in the very heart of an optically homogeneous medium. I am here taking for granted that the polarizing angle of 45° established by observation is rigidly correct."

Here is just where Professor Tyndall is, I believe, wrong. The angle is not "rigidly correct;" more accurate observation would, I am convinced, prove it. But to demonstrate it from theory:

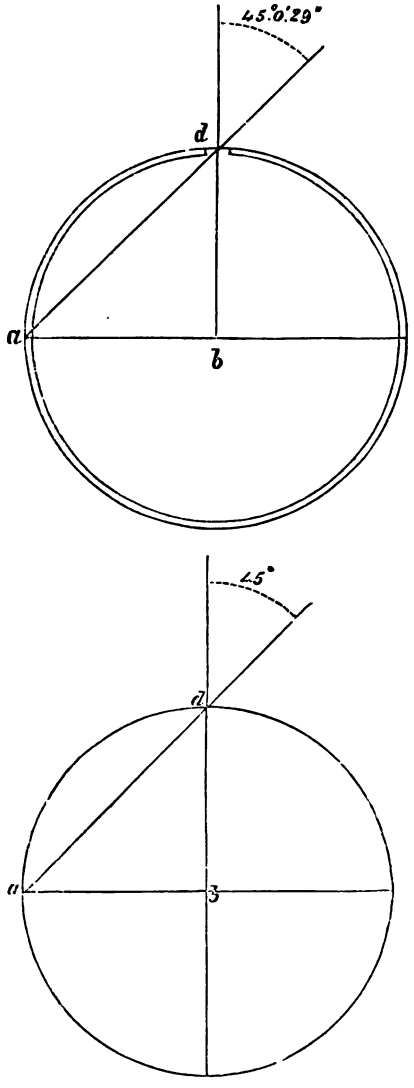
Air at the ordinary density has a refractive index 1·00028. By the law which I have already given, the completely polarized ray is that which meets the sphere of attraction at its intersection with the plane of the equator. The sine of the angle which this ray makes with the perpendicular is of course the equatorial radius of the atom divided by the distance

of the pole from the point where the ray meets the intersection of the radius and the sphere of attraction, *i.e.* $\frac{ab}{ad}$ (fig. 32).

$$\frac{ab}{ad} = \frac{1{\cdot}00028}{1{\cdot}4144115} = {\cdot}7072057 = \text{sin. } 45° \; 0' \; 29''.$$

Hence it follows that the light of the sky is completely polarized at an angle of 45° 0′ 29″, which, experiment will some day I trust show, is "rigidly correct," provided the air be at the ordinary density. That the angle will vary with the change in density of the air is clear, but it will always vary within certain limits, never however falling to 45°. It may increase in value half a minute; and in confirmation of this I may state that Dr. Rubenson, of Upsala, —quoted by Professor Tyndall,—gives it as 45° 1′.

The learned professor asks, "What known substance possesses an index of refraction to correspond with this polarizing angle, 45°?" I would suggest that the Original Element is this substance; for when the two spheres of attraction and repulsion are in contact, the tangent of the angle of incidence gives an angle of 45°.



Figs. 32 & 33.

I see nothing very startling in the conclusion of Brewster and others about the reflexion of light being from the particles of air themselves; Herschel expresses his surprise by remarking that in that case "the reflexion would have to be made *in* air upon air!" Why this should be so hard to believe I know not, when these philosophers must surely know that air is not a homogeneous substance, but one composed of oxygen, nitrogen, carbonic acid, &c., each of which has a critical angle of its own, and would therefore produce its own effect in reflecting some rays. Each of these substances is as much a different substance as glass is from diamond. From these we know that there is a reflexion in proportion to the difference between their refractive indices; and from the common surface of two different substances having the same refractive index there is *no* reflexion.

Granted that this is satisfactory, Herschel considers that "its explanation, when arrived at, will probably be found to carry with it that of the blue colour of the sky itself." On this I would remark that when the sun's rays

strike at a very great angle of incidence upon the outer surface of the atmosphere—and there are rays constantly doing this—the blue portion is transmitted and the complementary *yellowish red* is reflected back into space as earth-shine. It continually happens, too, that some rays which are transmitted into lower strata of atmosphere again undergo decomposition—for it is evident that none but perpendicular rays are ever for a moment composed of the same coloured rays—and through meeting substances, such as clouds, of comparatively high refractive power, the portion which would have proceeded up to the uppermost surface of the atmosphere is reflected towards the earth, forming the tints of sunrise and sunset; and these phenomena we know are constantly being produced over the face of the globe.

CHAPTER XIV.

CONCLUSION.

IN conclusion, if the reader has felt that, in my having brought before him some very elementary knowledge in philosophy and science, his wisdom has been outraged, I must crave his pardon, trusting that this, coupled with—what I am bold enough to believe is the truth—the fact that I have given him some *new* thoughts on a subject of paramount importance will be regarded as ample compensation.

I trust I shall lay myself open to no charge of want of modesty in presenting my claims if I state that I believe I have given the key which will unlock many mysteries in the world of philosophy and science. It would be the veriest hypocrisy in me if I said that I considered my efforts as a *very humble* contribution

to science. I say nothing of the kind, and indeed could not, since I am bold enough to believe that what I have advanced will do much to unsettle—ay, overturn—what have for hundreds of years held their ground as physical truths, and at a time, too, when there is so much evidence around that physical science is about to pass through a most critical phase. But while I claim no little, I must candidly admit that, without the labours of those who have preceded me, I could have done absolutely nothing. I have not hesitated to take the heterogeneous mass of material supplied by every eminent man from Thales to Kant, and out of it to construct an edifice which, harmonizing in all its parts, will, I trust, defy all the insidious workings of Time with all the power that either Talent can produce or Ingenuity afford; but it is to the labours of Snellius, Newton, Faraday, and other great workers in the *scientific* world, that I am chiefly indebted. When I say that I have pursued these inquiries for years, and have in no single instance ever made an *experiment*, the reader will clearly see how much I owe to the

labours of my predecessors. A ruler and a pair of compasses—Euclid's sole apparatus,—these form the "valuable collection of philosophical instruments" with which I entered upon and pursued my work.

There are many points in connection with the subject—some of them original, some as set forth by experimentalists, of the accuracy of which I have grave doubts—of which, had I but the time and opportunity to test them for myself, I might have been able to speak with certainty; for the present I must consign them to the uncertain future, with a hope that I or some other may be able hereafter to examine them.

In laying the preceding pages before the scientific world, I trust they will be found accurate in the main; they must—being but the opening up of a great subject—necessarily be in some respects imperfect. I do not claim infallibility; I may have reason at some future time to modify my views; if so, it will follow only upon future investigations in the subject proving my theory to be defective. I have, however, great confidence in the power of

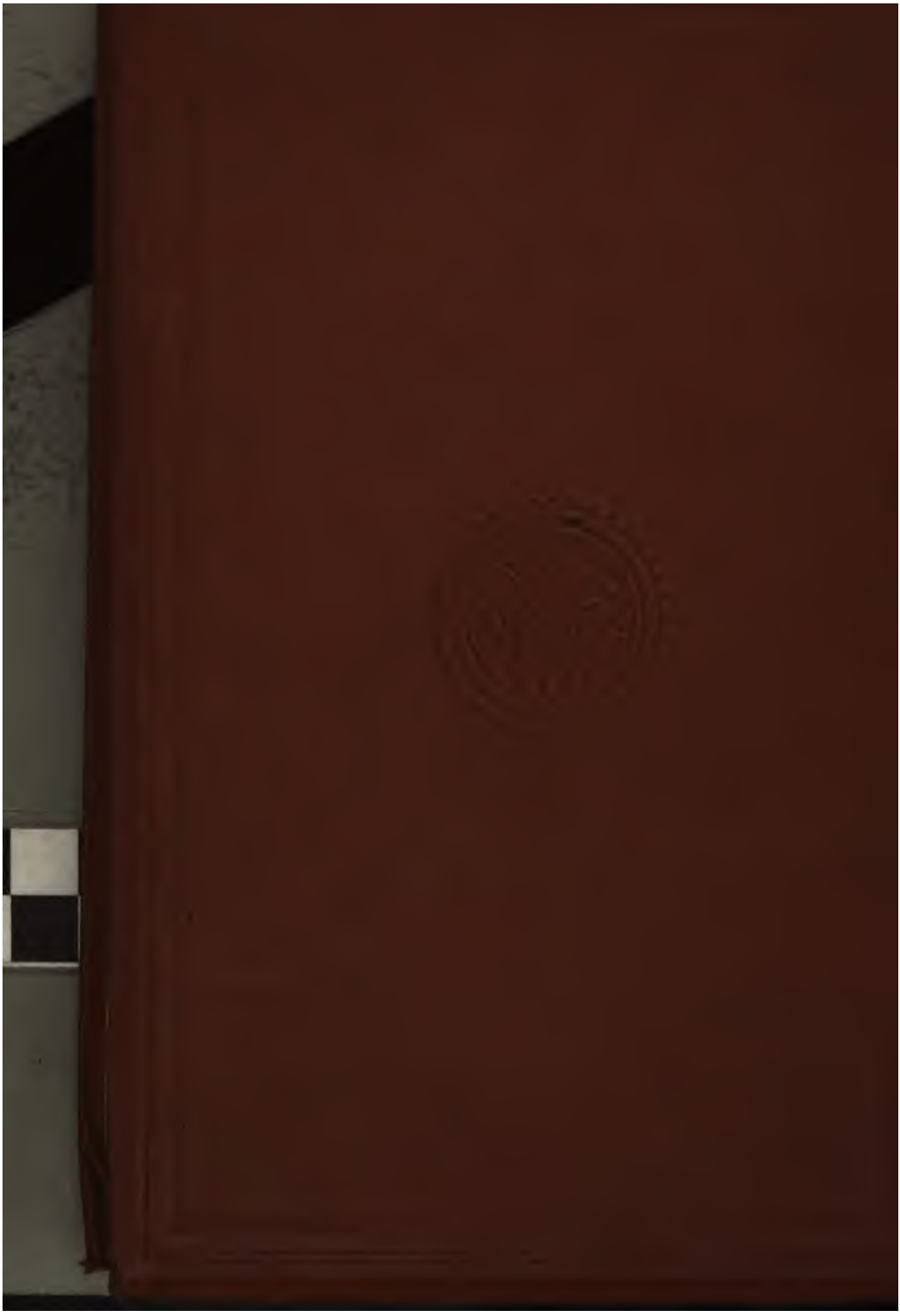
geometry and mechanics, and in my application of them to explain the phenomena of Nature.

I could wish to have been able to introduce to the reader's notice some researches in Chromatics, reflections on Double Refraction, Polarization, and Interference, together with some speculations on Heat, Electricity, Magnetism, and Chemistry, in so far as they bear upon this subject; but want of time keeps them still "a rude undigested mass" of notes.

I should much have liked to have kept the whole subject in my own hands, to investigate it in all its branches; indeed, I attempted to do so; but I found I was, as it were, in a lane which gradually widened, until it at last opened out into an unbounded field, and I gave up the attempt as hopeless.

This—together with the prickings of conscience that I could be no true lover of Science for her own sake, if I thus persisted in hiding my light under a bushel—not to mention the cares of this life, stern, matter-of-fact realities, which have often violently pulled up my

Pegasus as I have been careering through the boundless regions of Imagination, and brought me to the ground in such a forcible manner that it would have done old Samuel Johnson's heart good as he chuckled to himself, "No matter, indeed!"—this, I repeat, has induced me to come before a keen, cold, scrutinizing world, whose constant endeavour, *it is said*, is to discover a man's faults.

THE END.

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